Control ENGINEERING

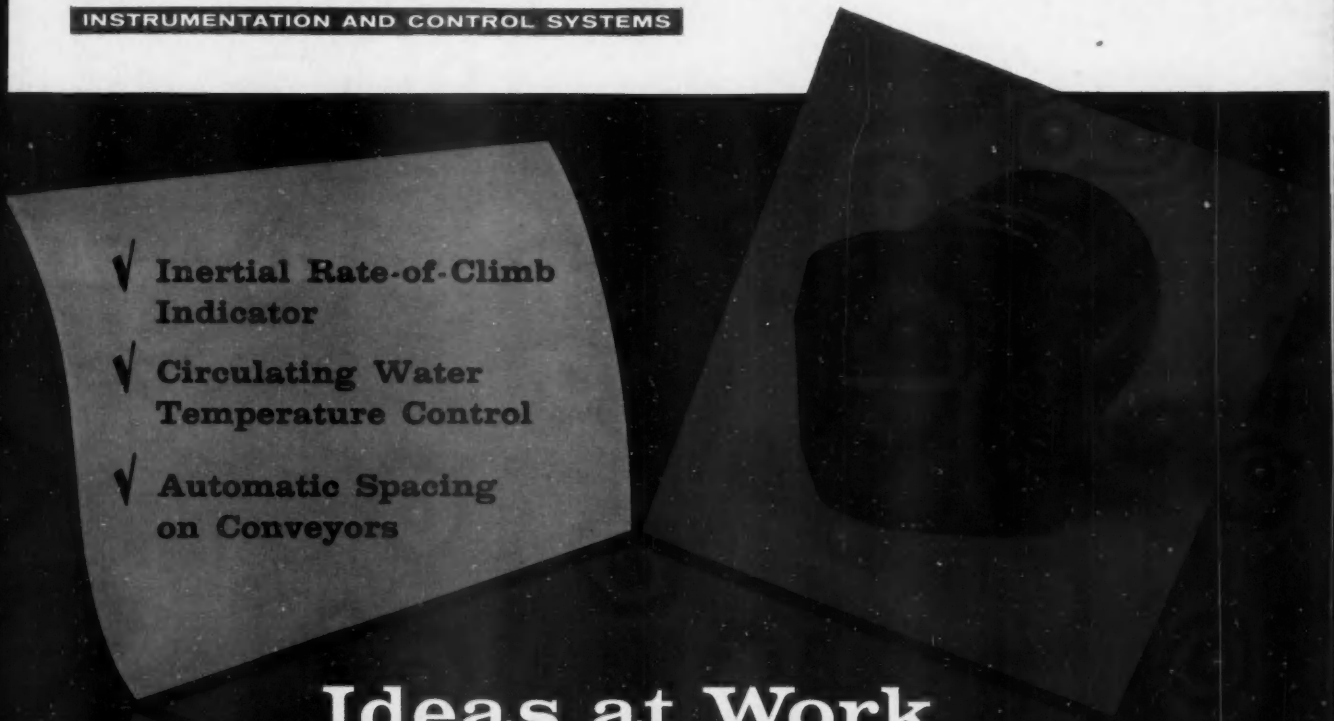
INSTRUMENTATION AND CONTROL SYSTEMS

A McGraw-Hill Publication

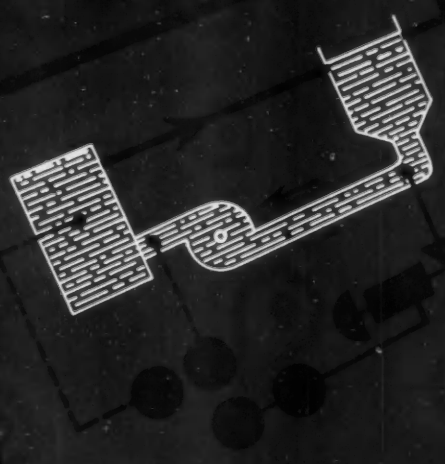
75 Cents

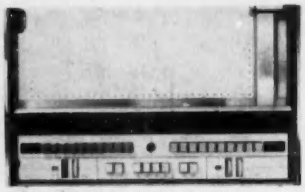
NOVEMBER 1959

- Inertial Rate-of-Climb Indicator
- Circulating Water Temperature Control
- Automatic Spacing on Conveyors



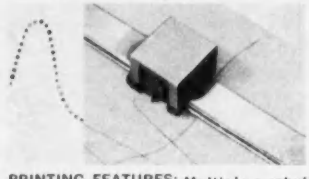
Ideas at Work





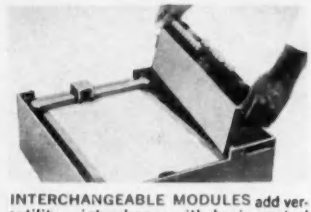
PUSH BUTTON PANEL controls operations rapidly, even at remote locations.

FLAT VACUUM PLATEN assures positive hold down of roll or sheet paper up to 12¼" width. Plot area, standard 10x15".

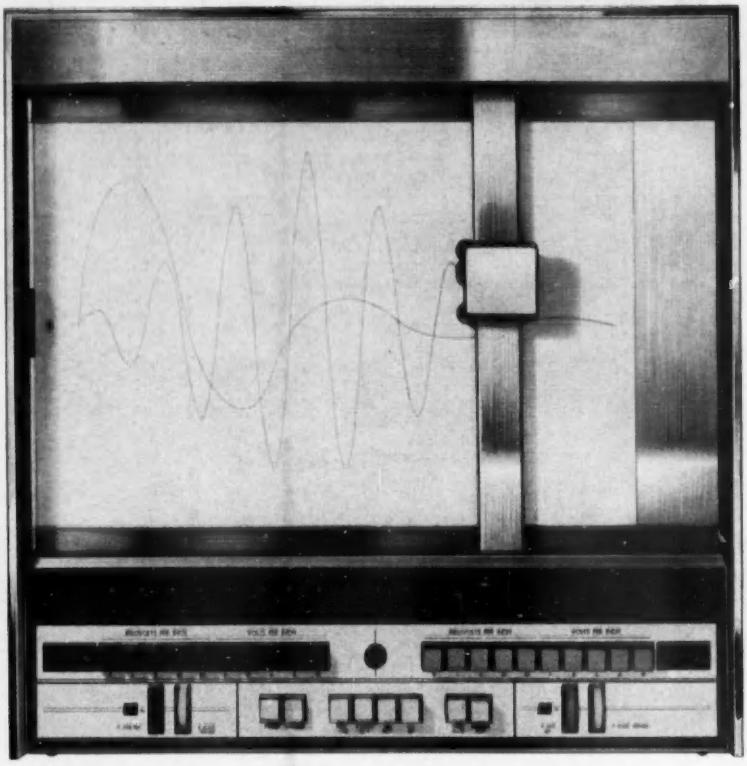


PRINTING FEATURES: Multiple symbol printing head—12 symbols...self contained ink supply.

Pen System—capillary action; splatter-proof. Point joiner available.



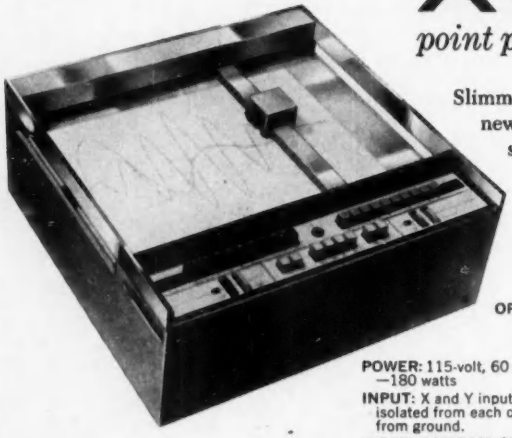
INTERCHANGEABLE MODULES add versatility...interchange with basic control section.



engineered for ease of operation...new

LIBRASCOPE X·Y PLOTTER

point plotting or continuous trace



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OPERATING INFORMATION

POWER: 115-volt, 60 cycle —180 watts

INPUT: X and Y inputs isolated from each other and from ground.

INPUT RESISTANCE: 2 megohms nominal on most scales. 1 megohm per volt on .5 millivolts per inch to .1 volts per inch scales.

INPUT SENSITIVITY: .5 millivolts per inch to 50 volts per inch with calibrated push button scales at .5, .1, 5, 10 and 50 millivolts per inch and .1, .5, 1, 5 and 10 volts per inch. Vernier controls permit continuous sensitivity adjustment between fixed scales, permitting full scale plotting for any sensitivity.

ACCURACY: Static .1%, dynamic .2% at 10" per second.

PLOTTER CALIBRATION ACCURACY: .05% on all scales.

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For full details—dimensions, applications, list of accessory equipment, call our Sales Engineering Department or send for illustrated brochure on Model 210, XY Plotter.

For information on career opportunities at Librascope, write Glen Seltzer, Employment Manager.

LI 9-20

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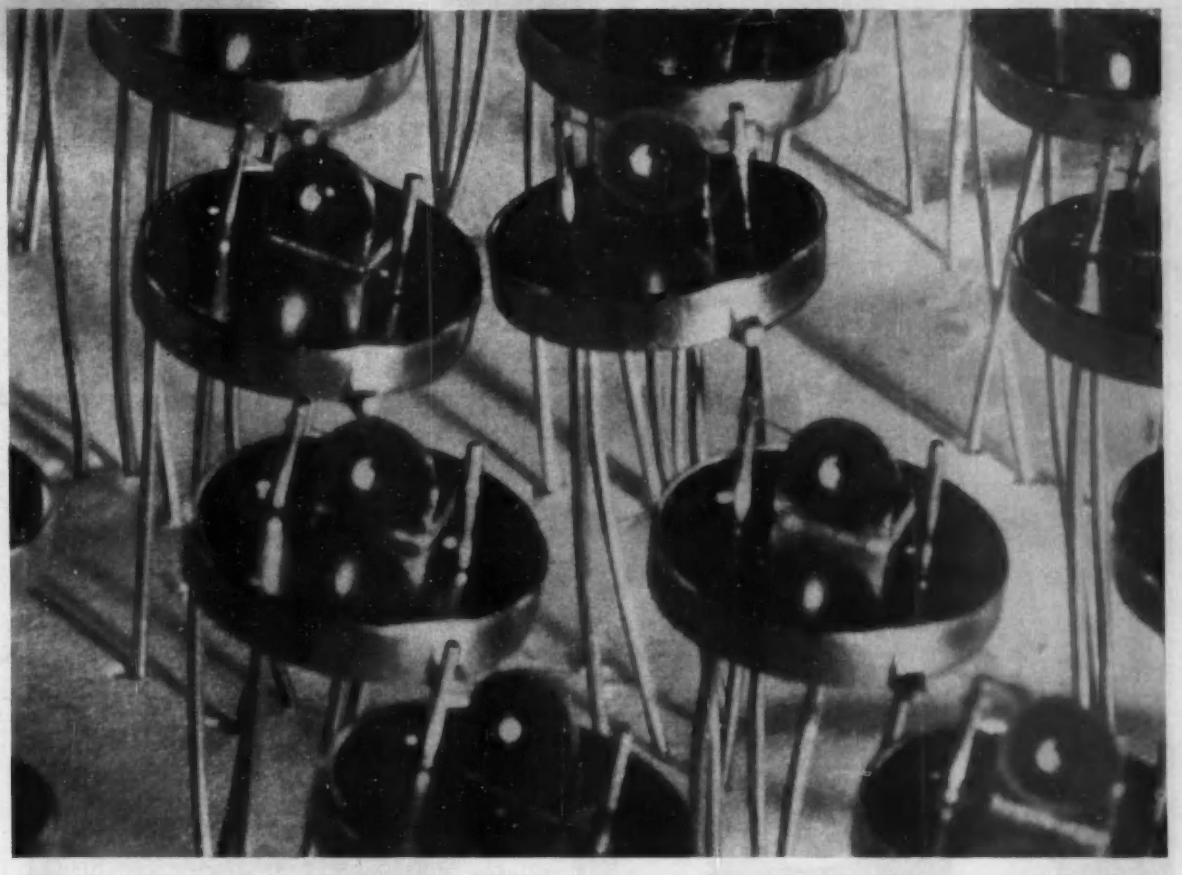
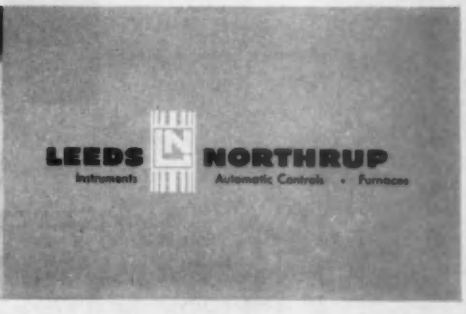


IBM, Poughkeepsie, N. Y.: Critical alloying and bonding temperatures determine final operating characteristics of germanium transistors (above).

Alloying and bonding temperatures a problem?

Not at IBM, Poughkeepsie, N. Y., where Speedomax® H is helping alloy the "dots" and bond the "whiskers" in the manufacture of transistors for their data processing equipment. The right alloy and proper bond depend upon temperature . . . determine transistor operating characteristics. At IBM, Speedomax H is holding these critical temperatures to within 2 degrees F . . . reproducing desired processing conditions, again and again. Rugged, compact and thoroughly reliable, this modern controller is providing equally dependable control for many other heat treating processes . . . helping to produce both process economies and a quality product. *Whatever your heat treat, it'll pay you to investigate Speedomax H! For details, contact your nearest L&N office or write 4918 Stenton Ave., Phila. 44, Pa.*



Operator loads CM furnace with tray of germanium wafers. Routine check with traveling thermocouple and Speedomax Type G AZAR recorder proves Speedomax H holds temperature gradient of soak zone to within 2 F.

A unique approach to problems of AUTOMATIC CHECKOUT and MONITORING

MSI — Monitor Systems Incorporated — is an autonomous subsidiary of Epsco, Incorporated . . . leader in the field of data control and a pioneer in the development and manufacture of automatic checkout and monitoring equipment. MSI offers technical talent of the highest calibre, backed by Epsco's long experience in this highly specialized field.

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Fort Washington, Pennsylvania

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Control ENGINEERING

NOVEMBER 1959
VOL. 6 NO. 11

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

103 **Japanese Tape-Controlled Milling Machine**
T. KAIWA and S. INABA of Fuji Tsushinki Mfg. Co. reveal a three-axis continuous-path numerical system using a digital servo operating from tape recorded pulse streams.

109 **How to Make the Bid Request Pay Off**
W. D. BELL of Tucson, Arizona, presents a check-list of nine key points that should be kept in mind when putting together an invitation to bid on a complex control system.

113 **Power Switching with Junction Transistors**
A. N. DeSAUTELS of Maico Electronics covers the theory of junction transistors in large-signal switching with adequate detail for preliminary design of control circuits.

119 **Using the Root Locus—Part II**
T. JAWOR of Evershed & Vignoles, London, illustrates the calculation of step and transient response from locus and shows how to apply method to multiloop systems.

124 **Progress Report on OPCON—Dow Evaluates Optimizing Control**
J. W. BERNARD and F. J. SODERQUIST of Dow Chemical tell of the technical and economic success of optimizing control after evaluating first installation of OPCON.

129 **How to Specify Resolution for Potentiometer Servos**
H. GRAY of Technology Instrument Corp. employs extension of the describing function technique to analyze the relationship between resolution and servo system performance.

135 **New Uses of Static Magnetic Components in Protective Circuits**
J. W. BUTLER of General Electric discusses a circuit for undervoltage protection and one for overvoltage; first developed for aircraft, they may be usable by industry.

139 **Data File 31—A Template for Designing Servo Compensation**
B. L. POTTS of USN and *G. J. THALER* of USN Postgraduate School use a simple template for designing servo compensators directly on the decibel vs phase angle plot.

144 **Electronic Teaching Machine Trains Keypunch Operators**
G. PASK of System Research and *D. WISEMAN* of Solartron Industrial Controls describe a machine that drills students, grades performance, and varies learning pace.

149 **A NOR-Element Timing Circuit**
H. SCHWAB of Consolidated Electrodynamics points out how standard NOR-elements can be used to synthesize any of the basic timing functions required in automatic systems.

---

155 **Simple Circuit Controls Spacing on Conveyor Lines**
R. L. DeLOACHE of Cleveland Electric automatically spaces cushions on paint line.

157 **Temperature Control of Short Circulating Water System**
D. W. RICHMOND of Monsanto gets optimum operation of special heat exchanger.

159 **Inertial Techniques Improve Rate-of-Climb Indicators**
B. FORD of Summers solves accuracy problem with photocell and inertial techniques.

161 **Pulse Circuitry for a Transistorized Photocounter**
W. N. SICK of Texas Instruments counts breaks in beam of less than one millisecond.

Continued on next page ➧

What's New in the Control Field

21 **Newsbreaks in Control**
Numerical control service policy, computer-controlled pilot plant, magnetic tape tester.

22 **A Control Engineer's Busy Week in Chicago**
ISA Show and Conference led off a crowded week of control activities in hot Chicago.

30 **IFAC Works and Plays, American-Style**
Chicago general session of IFAC elects new officers and hears report on Moscow Congress.

36 **Generalized Problem Stirs Up Computing-Control**
Effort to compare computers for process control has users watching, makers squirming.

43 **European Machine Tool Show Disappoints**
Activity in numerical control is slow; only one machine of 4,000 uses static control.

46 **Benson-Lehner's New Approach to Control**
West coast company will soon be in every facet of control with systems and components.

17 **Control Personality—JOHN G. TRUXAL**
Control theorist tries to create an environment in which imagination can run rampant.

95 **Industry's Pulse—Competition's Murder in Computing-Control**
1960 will be good year in computing-control but more suppliers are entering the field.

101 **Editorial—Gifted Students Need You**
Opportunities abound to teach gifted students the principles and practice of the field.

163 **New Product Developments**
Analog computer features high speed memory and storage; small recorder takes 2,000 g's.

204 **Abstracts of Technical Papers**
A user recommends statistical methods to smooth introduction of computing-control.

6 Shop Talk
10 Feedback
197 Bulletins & Catalogs
210 New Books
214 Meetings Ahead
216 Reprints

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Position and company connection must be indicated on subscription orders. Single copies, 75c, except $2 for September issue. U.S. and Canada: one year, $5. Foreign, one year, $15. Second-class postage paid at Albany, N.Y. Printed in U.S.A. Title registered in U.S. Patent Office.

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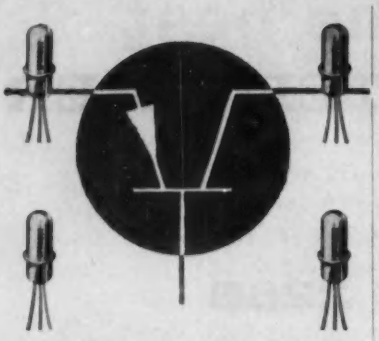
22



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Sprague 2N393 Micro-Alloy Transistors combine high gain with excellent high frequency response to meet demands of high-speed computer switching applications in the megacycle range. Low saturation resistance, low hole storage, and exceptionally good life characteristics make these micro-alloy transistors top performers in computer circuits as well as in general high frequency applications.

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SHOPTALK

Need a template to aid design?

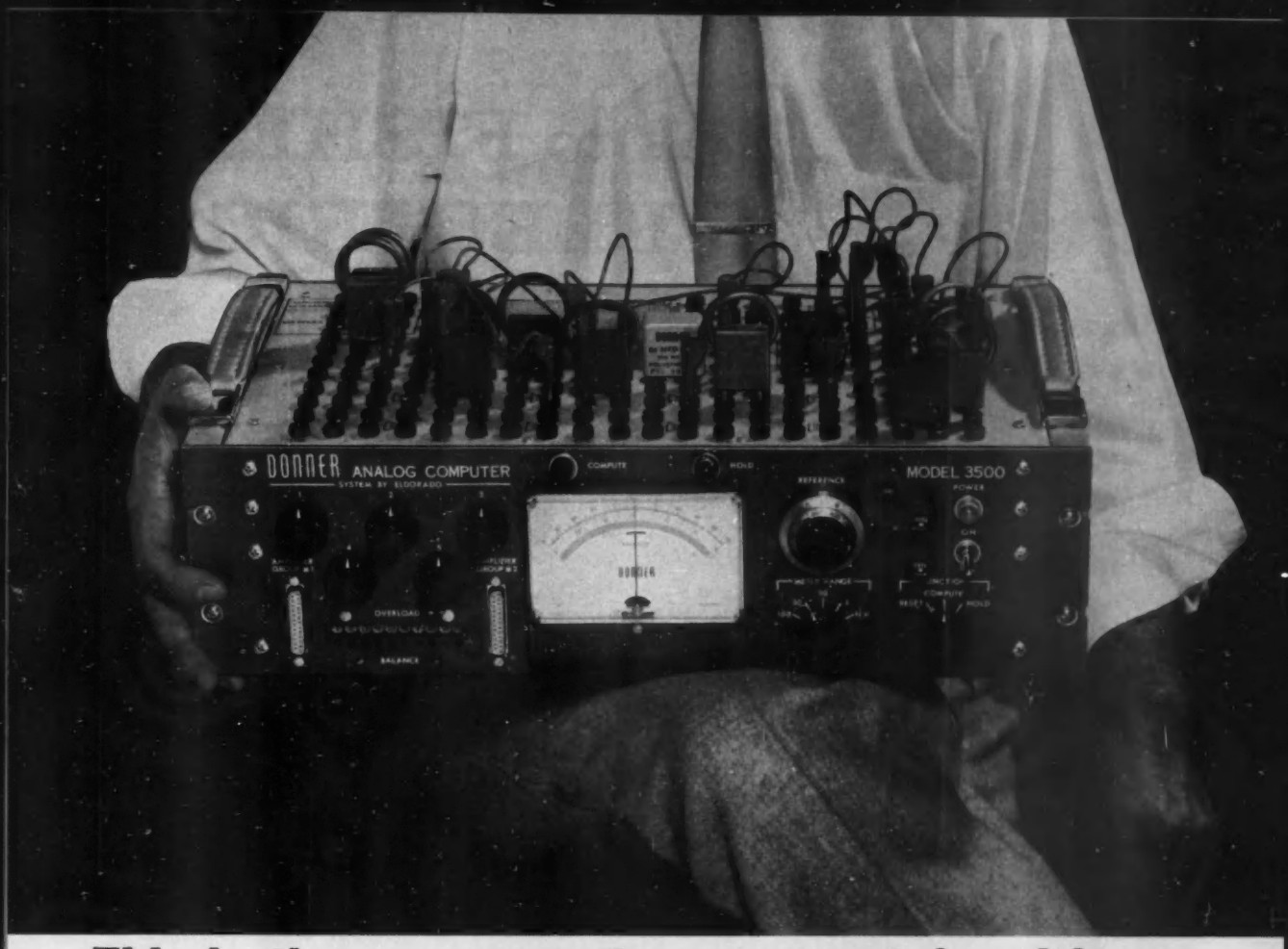
You'll note that the feature of this month's Data File ("A Template for Designing Servo Compensators", p. 139) is a decibel vs phase angle template useful for examing uncompensated servo performance and for checking the effect of compensators. Although reproduced in the article, the template really isn't much use unless it's on a sheet of transparent film. Looking into the reprint possibilities, we found that we can supply the template on clear acetate along with a copy of the Data File text at a cost of 75 cents. Since this is an untried venture, though, we'd rather not go ahead unless a sufficient number of readers express interest. Let CONTROL ENGINEERING's Readers Service Dept. hear from you if you'd be interested in receiving this handy design-tool package.

King sized do-it-yourself project

On a balmy Saturday in September, the entire CtE staff gathered at the Oceanside, Long Island, abode of Associate Editor John Cooney, to share the fruits of his summer-long labor—a first class, full scale, very enjoyable backyard swimming pool. Largely a one man project (with the help of some farsighted relatives—and in the latter stages a few converted skeptics) the pool had the rest of us discussing the availability of swimming pool plans, where to get strong backs to wield shovels, how to get the concrete mixed, and the cost of auxiliaries. The statistics on the pool are impressive—12 x 27 ft and 7-ft deep, it took 75 cu yds of concrete, holds 18,000 gal of water, was completed in four months, and is hooked into the house heating plant so that you don't have to swim in chilly water. That satisfied look on John's face as he gets ready to dive is well justified.

A sampling for December

Here are some of the topics that you can look forward to in the next issue: how the missilemen keep the Thor IRBM operational, a new approach to the design of surge vessel control systems, data processing for point-to-point numerically controlled positioning systems, a rundown on the digital codes employed by the most popular general purpose computers, and a practical guide to the design of thyratron circuits for controlling electromagnetic devices.



This is the one computer you can take with you

Announcing the Donner 3500

SMALLEST ANALOG COMPUTER EVER MADE

FITS YOUR LAP, YOUR DESK, YOUR BENCH!
Until now, the engineer, teacher, or scientist who needed an analog computer on the job faced an awkward situation. He could take his problem or class to a computing center and wait his turn or, after a thoroughly cumbersome undertaking, set up a big computer on the site. In any event, the task was costly and time consuming.

WEIGHT: 23 POUNDS
A complete computer is only 5¼" high, 19" wide, and 10¼" deep. By simply removing a few screws, the problem board tilts up for rack mounting.

The Donner 3500 furnishes big computer performance in a tiny package. Up to three computers can be slaved together for 10, 20, or 30 amplifier problem solving capacity. Choose 0.1 or 1.0 percent computing components. Amplifiers are available in both stabilized and unstabilized forms. Anytime, unstabilized amplifiers can be converted by adding a plug-in component.

OPERATION SIMPLE, APPLICATIONS BROAD
If you can run a slide rule, you can use the Donner 3500. It's just that easy. Most dynamic equations can be solved and demonstrated. You can solve servo-loop and process control problems on the job with no loss in time. Alternately, use it in the lab as a precision power supply, a low-frequency oscillator, wave analyzer, or function generator.

PRICE
Prices for the Donner 3500 complete and ready to work including the "extras" range from $1200 to $1800. This includes potentiometers and a nominal selection of computing components. A full complement of accessory equipment such as function generators, transport delay generators, and multipliers is available.

WANT MORE INFORMATION?
Your nearby Donner engineering representative will be happy to give you complete information on the Donner 3500 and arrange a demonstration. Or you may write Department 0811.

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CONCORD, CALIFORNIA

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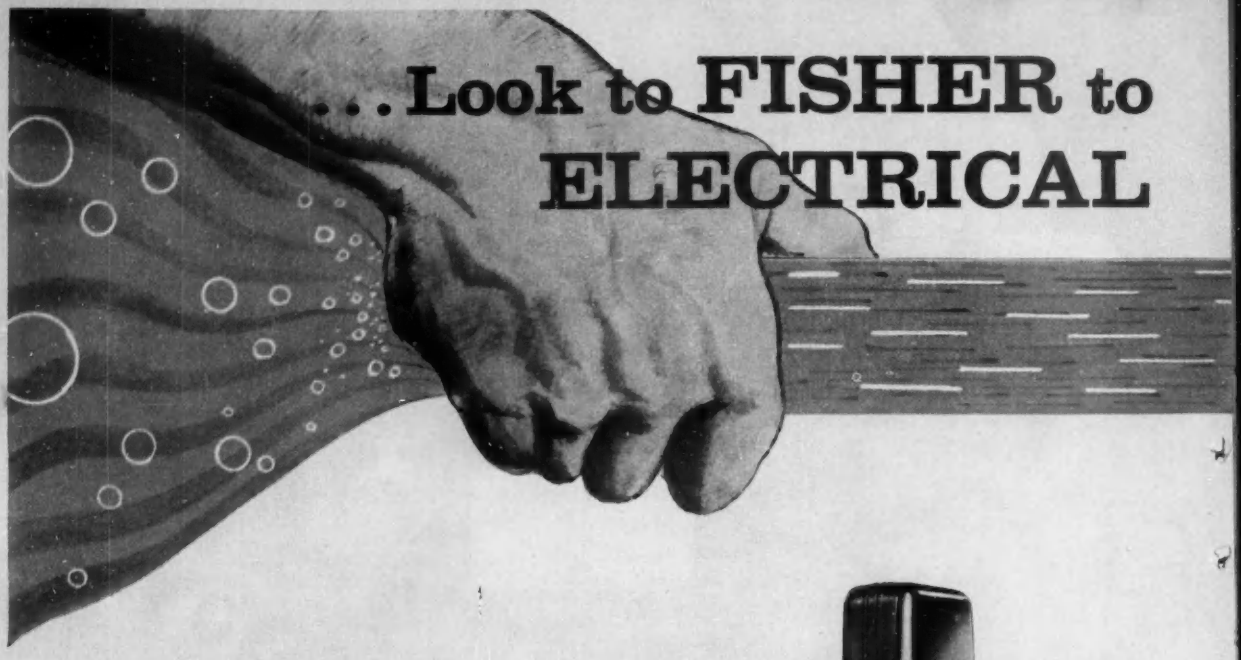
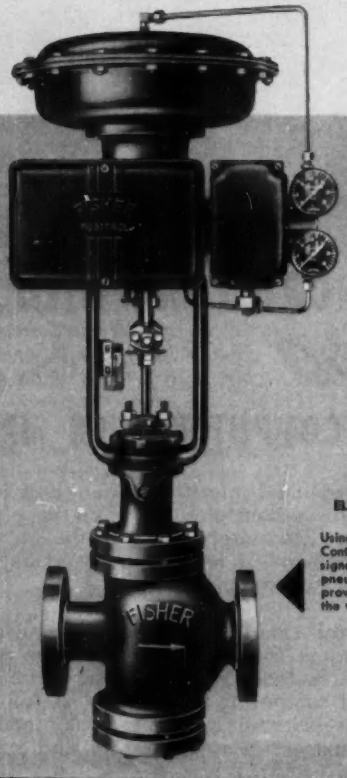
...Look to FISHER to ELECTRICAL





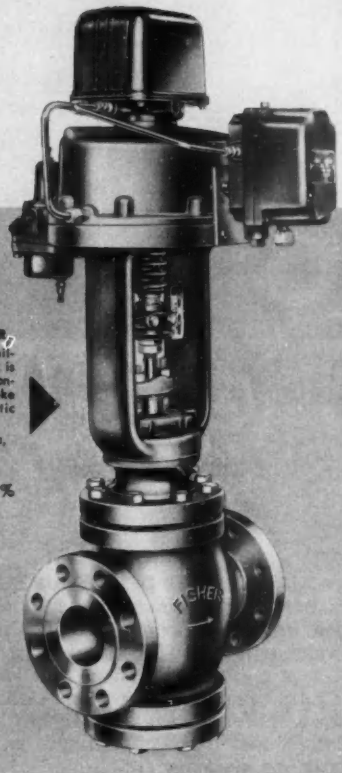
THE PNEUMATIC OPERATED PISTON "P.O.P." WITH ELECTRO-PNEUMATIC TRANSDUCER

The compactness, speed and power available from the FISHER Series 470 P.O.P. is readily made available in electrical control systems with the use of the yoke mounted Type 545 Electro-Pneumatic Transducer.

Input Current: 1 to 5 ma, 4 to 20 ma, 10 to 50 ma, d.c.

Linearity—1% of Full Range

Resolution Sensitivity—Less than 0.1% of Input Range.



THE ELECTRO-PNEUMATIC POSITIONER "E-POSITROL"

Using a conventional Fisher diaphragm Control-Valve, the E-Positrol receives a Ma signal and translates this to a proportional pneumatic signal to a positioner which provides the speed and power to operate the valve.

Input Current: 1-5 ma; 4 to 20 ma, 10 to 50 ma D.C.

Linearity—1% of full scale.

Resolution Sensitivity—0.1% of input range.

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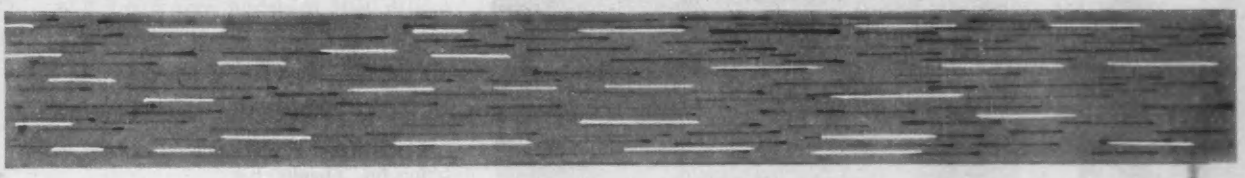
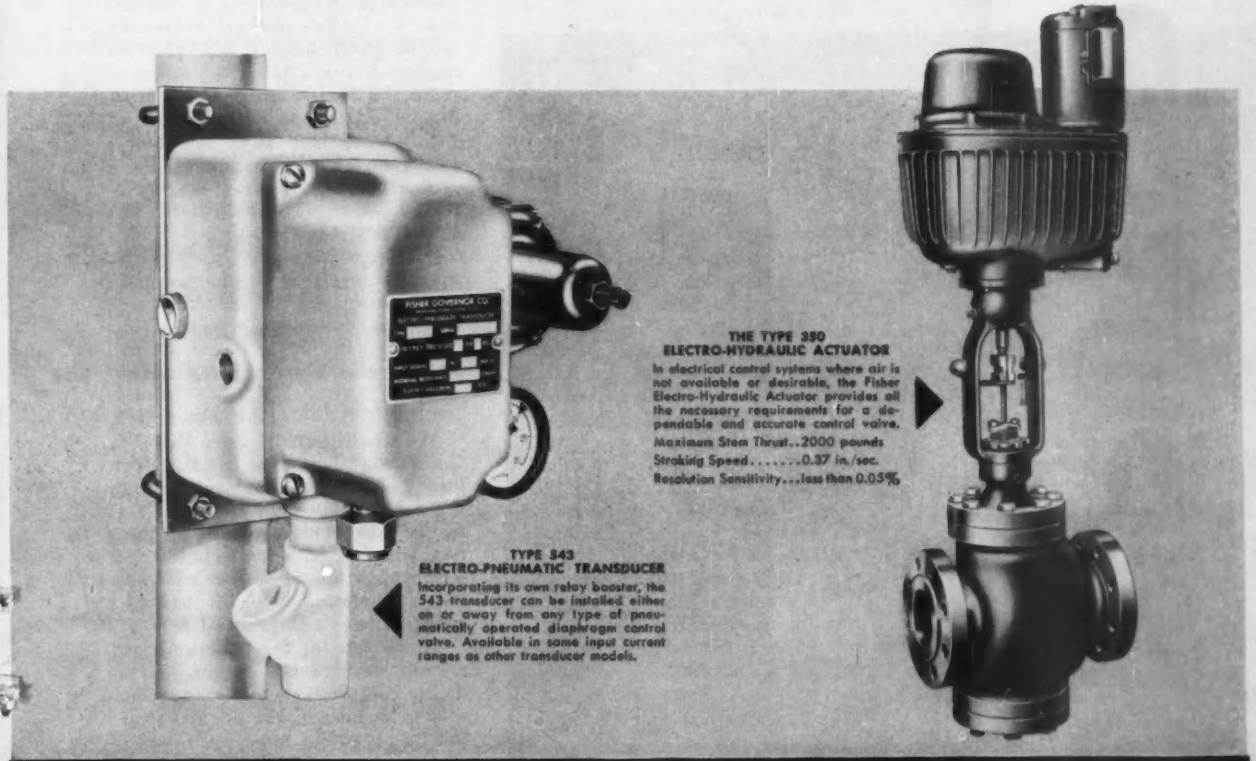
supply the muscles for your CONTROL SYSTEMS



The old adage, "a chain is as strong as its weakest link" can be equally applied to the "muscle" or more correctly the final control element on any control loop. The importance of a control valve in an electronic system should never be considered lightly and that is why you should look to Fisher for assurance in furnishing dependable and accurate control valves for your electrical or electronic system.

Described below are three types of actuators that offer an exceptionally practical and economical approach for control valves in electrical control loops.



TYPE 543 ELECTRO-PNEUMATIC TRANSDUCER

Incorporating its own relay booster, the 543 transducer can be installed either on or away from any type of pneumatically operated diaphragm control valve. Available in same input current ranges as other transducer models.

THE TYPE 350 ELECTRO-HYDRAULIC ACTUATOR

In electrical control systems where air is not available or desirable, the Fisher Electro-Hydraulic Actuator provides all the necessary requirements for a dependable and accurate control valve.

Maximum Stem Thrust..2000 pounds
Stroking Speed.....0.37 in./sec.
Resolution Sensitivity...less than 0.05%

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TO THE EDITOR—

In the description of displacement-type liquid specific gravity instruments that appeared in "Physical Property Testers Check Product Specifications", pp. 102-106, April '59 issue, the authors have referred to the chain-weighted plummet principle. We believe this to be a reference to our Princo Densitrol . . . [in which a] . . . linear differential transformer on the outside of the sampling chamber senses position of a magnetic core enclosed in a chain-weighted plummet.

The Princo Densitrol can be used to spread a range span of 0.005 over the full scale of a typical recorder-controller with ½ percent of range sensitivity and provide completely automatic temperature compensation as well. Temperature compensation is a must on accurate and sensitive specific gravity measurements.

Raymond A. Weinmann
Precision Thermometer & Instrument Co.
Phila., Pa.

Claims there's a better way.

TO THE EDITOR—

In his May '59 article (on improved computing technique in control system analyzers) in CONTROL ENGINEERING, Mr. A. M. Fuchs describes the computation of phase angles by first multiplying the system's output signal by a reference sinusoid, followed by integration of the product. When the integral is taken over a complete cycle of the reference sinusoid and the reference sinusoid is a cosine voltage, the value of the integral is π times the coefficient of the fundamental cosine component of the Fourier series for the system output. Use of a sine for the reference sinusoid yields π times the coefficient of the fundamental sine component of the Fourier series for the output.

The multiplier is not required if a method described by L. Pode on page 25 of Cyclone Symposium II is used. Pode's method computes

$$\int_0^{\frac{2\pi}{\omega}} F(t)\cos\omega t\,dt$$

and the corresponding sine integral by the equation

$$\frac{d^2y}{dx^2} + \omega^2 y = \omega F(t)$$

for zero initial conditions. Mechanization of his method requires only summing and integrating amplifiers. The replacement of the multiplier by such linear computing elements could, in my opinion, reduce system analyzer costs and improve accuracy, particularly at low signal levels, by an order of magnitude.

Emile S. Sherrard
National Bureau of Standards
Washington, D. C.

A ten-to-one improvement is worth trying for. Thanks. Ed.

Did we forget something?

TO THE EDITOR:

I have recently read the fine description of Nat Cohn in the August issue of CONTROL ENGINEERING. However, I believe that it omitted mentioning very significant contributions of Nat.

Nat was the primary spark for obtaining the translation of four Russian journals on instrumentation. As chairman of the ISA publication committee, he greatly assisted the ISA Aeronautical Division in the publication of its special Missile Issue (*ISA Journal*, Nov. 1958). Also, he was largely responsible for the ISA's adopting a solid transactions publication policy.

As you may well know, he will be the Industries vice-president for ISA for the next two years.

I have great sympathy for your editor in his tough job of summing up in a few paragraphs the numerous contributions of a really fine man.

W. J. Gabriel
(Past Director ISA Aero Div)
Convair
Fort Worth, Tex.

We wholeheartedly agree that Nat Cohn's contributions to ISA have been great. They have also been great to AIEE. But, since our space available for the story would not allow adequate description of both his technical and society contributions, we chose to give full attention to his technical contributions to the control field.

Thank you for the opportunity to publish some of the information on society contributions that we were unable to include in the original story. Ed.

Familiar shoptalk

TO THE EDITOR:

In the May "Shoptalk" I noticed that perforations are here to stay. GOOD! Now make it a better magazine by interspersing something between worthwhile articles so one does

- Lightweight . . . only 8.5 oz.
- Superior Linearity and Hysteresis Characteristics
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Porting modulated flow to linear or rotary actuators with respect to minute input current has been optimized within a small envelope and at a weight that is approximately 30% less than other valves of similar capacity. Design also provides for interchangeability with many existing servo valves now used in airborne applications. For further information, ask for technical bulletin number SE-98.

Packaged with Vickers standard (left) or miniaturized (right) piston type hydraulic motors, the assembly provides excellent performance with the added advantage of single-source responsibility.

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CIRCLE 11 ON READER SERVICE CARD

New UNION readout instruments withstand shock, vibration and extreme temperature changes

Union Switch & Signal's new READALL* readout instrument replaces complicated systems of lights and relays for reading, storing or transferring all types of information for industrial and military applications. It is not to be confused with conventional indicating devices.

Designed to meet requirements of MIL-E-5422D. The new READALL readout instrument is precision-built and provides instantaneous and continuous operation under conditions of shock, vibration and extreme ranges in temperature. The digital display includes characters in numerical sequence from 0 to 9 plus two blank spaces. 7/32-inch characters can be illuminated red or white as desired; when not illuminated, they appear white against a black background.

Reliability. Performance through one million random operations is an inherent feature of the new READALL instrument. Each module is gasket-sealed in its case to exclude moisture and seal out foreign particles. An especially thin enclosed DC motor, containing ball bearings, permits more efficient operation.

Modular Construction. A unique feature of the readout instrument is its modular construction. It can be used individually or in groups to display multiple characters in a single case.

Direct Code Translation. The operation of the READALL readout instrument is based on a positioning system using a four-bit code. The visual display is the result of a direct electro-mechanical conversion of a binary signal to a decimal read-out. There is no need for additional conversion equipment. Separate code and motor circuits permit the use of the readout instrument in low-level circuitry.

Electrical and Visual Data Storage. Once positioned, the information is displayed until a new code is transmitted to the instrument. No power is consumed while the information is retained. This data may be stored or read-out electrically for further transmission or recording.

Operate Time. The operate time varies from 0.1 second to 1.0 second depending on character position.

Weight and Size. Maximum weight including case is seven ounces; without case, four and one-half ounces. Size encased is 5 13/64 inches long, 1 47/64 inches high and 39/64 inch wide. The new READALL instrument is designed for operation over a temperature range of −54°C to +71°C in humidities up to 100% and altitudes up to 70,000 feet. For more information, write for Bulletin 1019.

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12 CIRCLE 12 ON READER SERVICE CARD

FEEDBACK

not require two copies to get all of the articles he wants. As an example, one article ends on page 105 and another begins on page 106. This second article ends on page 109 and another begins on page 110, etc.

C. D. Quimby
Bell Telephone Labs.
Whippany, N. J.

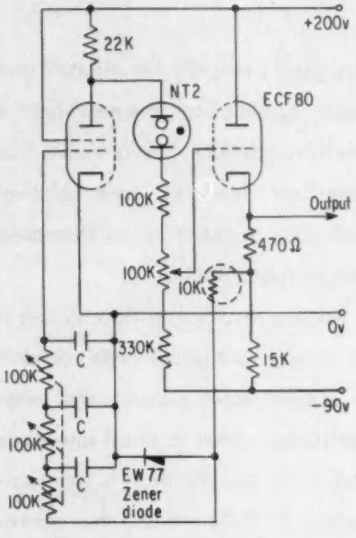
How about ads? See this issue for example. Ed.

Won't work without resistor.

To the Editor:

In your abstract of my article on page 183 of your July, '59 issue, a vital 10k resistor is omitted from the schematic. I show it ringed on the diagram below.

J. F. Young
Birmingham,
England



Put it in Spanish.

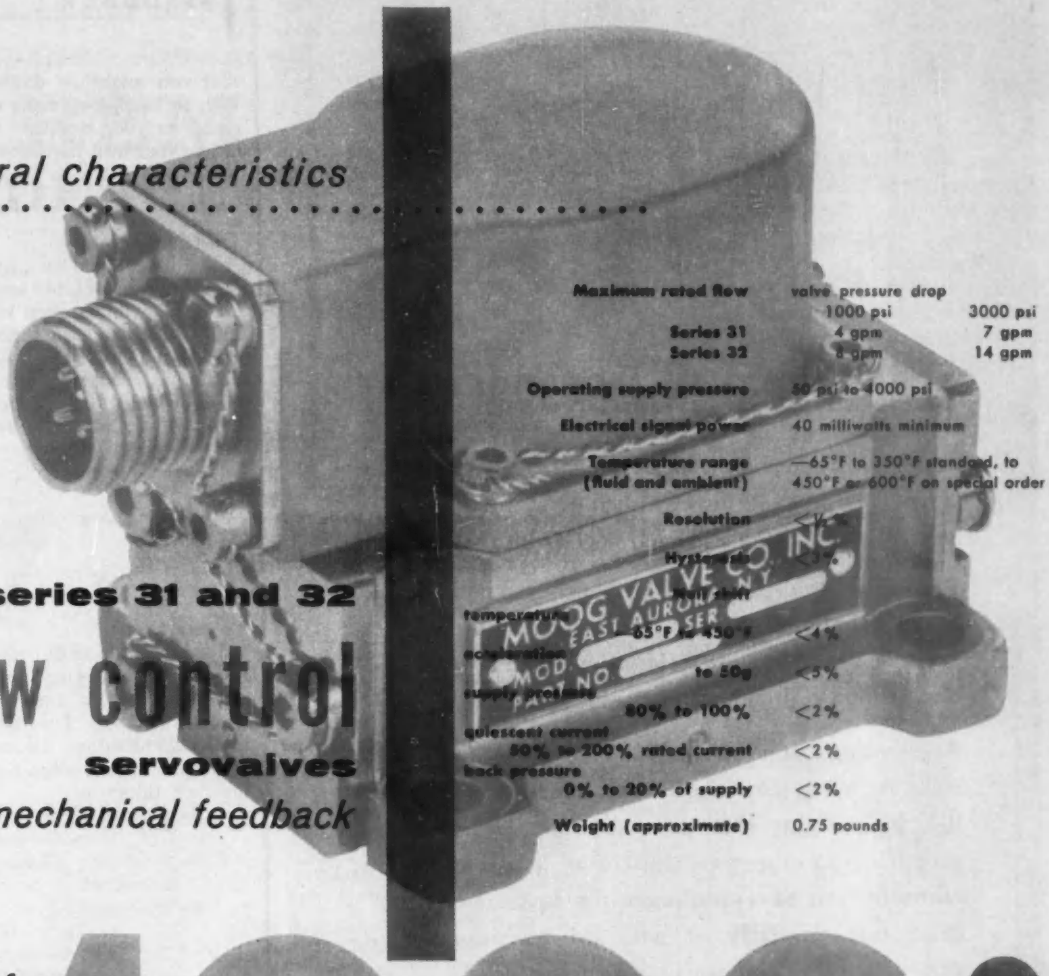
To the Editor—

Having recently joined the staff of YPF, I would be extremely interested in receiving a Spanish translation of the article, "Take a New Look at AC Motors for Adjustable-Speed Systems", that appeared in the June '59 issue. The contents of this article should be very useful in my technical work.

Rubens MacAdden
Yacimientos Petroliferos Fiscales
Tolosa, Argentina

Translation costs here would run to about three cents per word. I suggest that you can obtain a translation cheaper through the librarian at the engineering headquarters of YPF, or

general characteristics



	valve pressure drop 1000 psi	3000 psi
Maximum rated flow		
Series 31	4 gpm	7 gpm
Series 32	8 gpm	14 gpm
Operating supply pressure	50 psi to 4000 psi	
Electrical signal power	40 milliwatts minimum	
Temperature range (fluid and ambient)	—65°F to 350°F standard, to 450°F or 600°F on special order	
Resolution	<½%	
Hysteresis	<3%	
Null shift		
temperature —65°F to 450°F	<4%	
acceleration to 50g	<5%	
supply pressure 80% to 100%	<2%	
quiescent current 50% to 200% rated current	<2%	
back pressure 0% to 20% of supply	<2%	
Weight (approximate)	0.75 pounds	

series 31 and 32

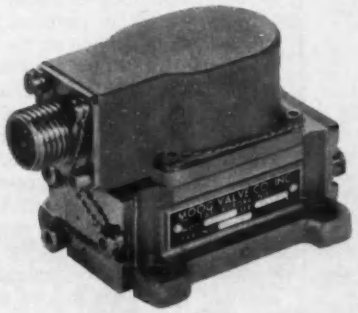
flow control

servovalves

with mechanical feedback

from

MOOG:



Series 31 and 32 servovalves are miniaturized two-stage flow-control valves which utilize internal mechanical feedback. Features of the new design include high performance, simplification and compactness, together with a wide temperature capability. Specific valve characteristics can be achieved other than the ones listed above.

Write for catalog 310 and individual model data sheets that illustrate typical performance variations.

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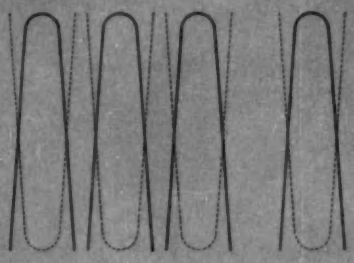

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Recognizing that no one line can include the ideal instrument for every purpose, Statham has further exercised the responsibility that devolves upon leadership by preparing an objective, illustrated booklet entitled "Introduction to Transducers for Instrumentation." Brief but scholarly, it will aid instrumentation and project engineers in surveying all 16 major transduction principles, including but not limited to those used in Statham products.

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FEEDBACK

that you might sit down at a table with an English-speaking electrical engineer in your company and thereby obtain your own translation. Ed.

Fact of record

TO THE EDITOR:

We have noted on page 98 of the June, '59 issue of CONTROL ENGINEERING that credit is given to The Louis Allis Co. as being the registered owner of "AJUSTO-SPEDE". Inasmuch as Eaton Manufacturing Co. is the registered owner of the trademark and The Louis Allis Co. solely has rights to its use, we would like to have you make record of this fact.

J. R. Teagno
Eaton Manufacturing Co.
Cleveland, Ohio

What is it; how big is it?

TO THE EDITOR—

I am attempting to collect information on the growing importance of electronic control and programming of machine tools. I would appreciate receiving literature references pertinent to the above subject, also including such things as:

1. Predictions of the future expansion of automated machines.
2. Need for the machine maker to build-in controls to compete in machine sales.

R. G. Rowe
The Carborundum Co.
Niagara Falls, N. Y.

We have had two extensive treatments of this subject recently. The first is a three-part article beginning in January 1958 which described the operation and performance characteristics of 31 different numerical positioning systems. The second, our entire September issue of 1958, was devoted exclusively to program control. And see our evaluation of the market in last month's "Industry's Pulse".

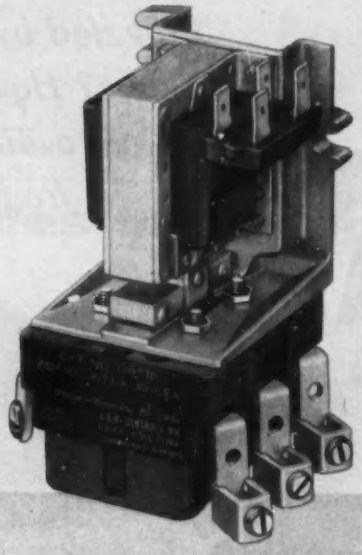
The development to be watched very carefully is the Kearney & Trecker Milwaukee-Matic. This is the first manufacturing machine developed specifically for numerical control; in the past, numerical controls were largely applied to existing designs of machines. We believe that the K & T development marks the beginning of a "control" revolution in the machine tool business and that many other builders will develop machines similarly radical in design. The big market for electronic control will be in new machines and not in retrofit. Ed.

S-40 CONTACTOR

Another advanced

RBM DESIGN

for the Air Conditioning Industry



E ESSEX ENGINEERED E

The new S-40 is RBM's latest addition to its family of controls specially engineered for the air conditioning industry. More powerful than its S-30 teammate, the S-40 is similarly engineered and built to exceed the rigid requirements of the industry's largest users.

HERE IS EVIDENCE OF RBM'S METICULOUS ENGINEERING

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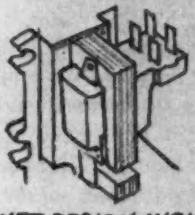
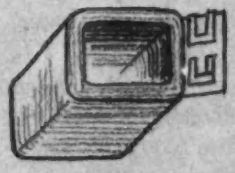
FILE NO. E-12139

LARGE DOUBLE BREAK SILVER ALLOY CONTACTS



MAGNET DESIGN INSURES POSITIVE CONTACT ACTION. NO KISS POSITION



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- COIL TERMINALS: DOUBLE QUICK CONNECT, SCREW TYPE, OR LEAD WIRES
- COIL RATING: 6 TO 230 V.A.C.
- POLE ARRANGEMENTS: 2 OR 3 POLES (2 DUMMY WIRING TERMINALS AVAILABLE ON 2 POLE DEVICE)

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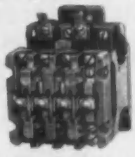
Specially engineered air conditioning contactor with contact ratings of 30 Amp. continuous, 180 Amp. inrush at 230 V. A.C. At 600 V. A.C. — 15 Amp. continuous, 90 Amp. inrush. Construction features same as Type "S-40".



TYPE "C-30"

2, 3 or 4 poles. 30 Amp. continuous, 180 Amp. inrush at 230 Volts, 25—150 Amp. at 440 Volts, 9—54 Amp. at 600 Volts. Parts, magnet coil, replaceable. Straight through wiring.

TYPE "C-50"

2—50 Amp. power poles plus 1 extra interlock contact available. 50 Amp. continuous—250 Amp. inrush at 230 V.

Consult your RBM product application engineer or write for Bulletins C-10 and C-7.

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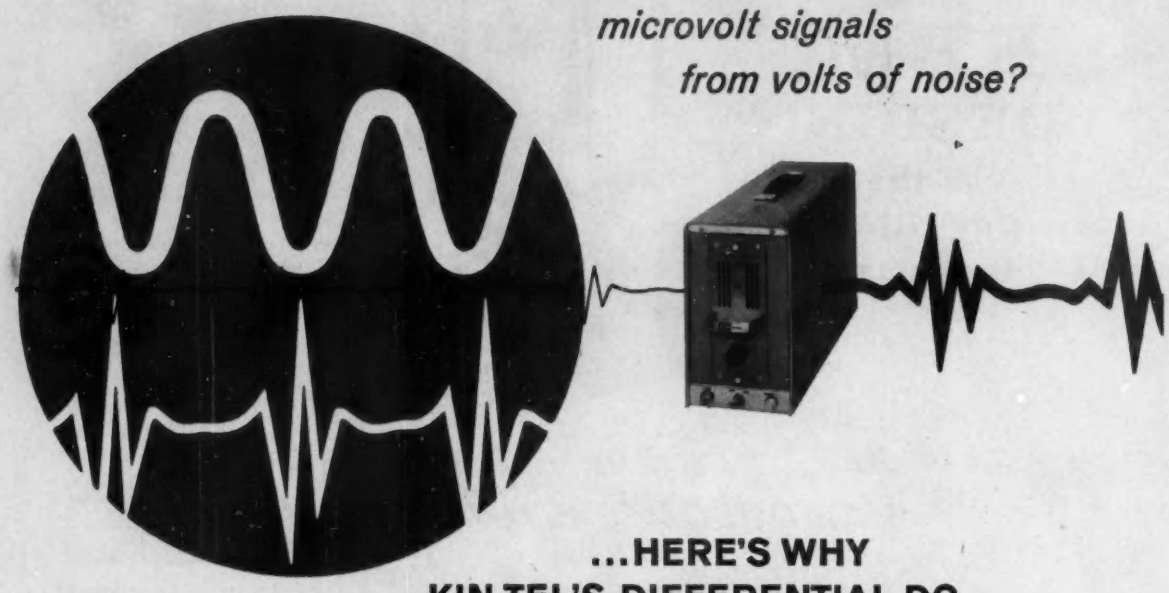
Puzzled by ground loop problems? How to rescue microvolt signals from volts of noise?



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These are just a few of the many outstanding features of the Model 114A differential DC amplifier...features that make this amplifier *really work* in instrumentation systems...features that will help solve *your* instrumentation problems today.

Ideal for thermocouple amplification, the 114A eliminates ground loop problems; allows the use of a common transducer power supply; permits longer cable runs; drives grounded, ungrounded or balanced loads; can be used inverting or non-inverting. Price $875.

For additional information and technical literature on this exceptional instrument, write or call KIN TEL—the world's largest manufacturer of precision, chopper-stabilized DC instruments.

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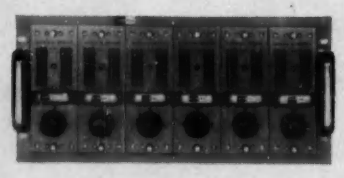

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John G. Truxal

stimulates the imagination

Give a good engineer an environment in which his imagination can run rampant, and he'll produce outstanding work. That about sums up the philosophy by which John Truxal runs the Electrical Engineering Department at the Polytechnic Institute of Brooklyn. It was just such an exposure that led Truxal into the control field in the first place and allowed him to develop into one of the U.S.'s outstanding control theorists, one who can combine theory with a practical slant.

In 1941 when he enrolled at Dartmouth College, Truxal planned to major in English. But a wartime accelerated program mixed up his plans and his courses. He received an A.B. degree while in the U. S. Navy, majoring in Physics—if in anything. The Navy then provided the stimulus and direction to Truxal's career. It sent him to MIT to study radar and thereafter assigned him to a job maintaining radar equipment.

The environment of MIT left its mark on sailor Truxal. After the war he headed back to Cambridge, earned a BSEE degree in 1947, a ScD degree in 1950. At MIT he worked first with Ernst Guillemin on circuit theory, then met the ubiquitous Gordon Brown who steered him into the control field.

For his doctoral dissertation, Truxal penned a thesis entitled "Synthesis of Control Systems". After graduation from MIT, he went to Purdue University where he taught electrical engineering for four years and adapted his doctoral dissertation into a book. Whether it was merely the timing—as John Truxal claims—or his early start in English coupled with outstanding technical competence—doesn't matter, the result is that Truxal's *Automatic Feedback Control System Synthesis** has become a best seller in the technical field. It is a book that few control engineers have not studied at one time or another. Probably Truxal's biggest contribution was the inclusion of certain new topics, like sampled data systems, at a time when engineers were anxious for such information.

His academic start as an English major left a lasting impression on Truxal, because he has turned into a more than usually active author. After finishing the book on synthesis, he edited the 19-section *Control Engineers' Handbook*,* which was the first such effort in the control field. His future writing plans are impressive, too. He's coauthoring a textbook on electromechanics. This manuscript, which stemmed from a course at Brooklyn Poly, will introduce electromechanical systems and energy sources to students in the junior year of engineering. And he's thinking about joining another Brooklyn Poly professor in adapting lecture notes into a textbook for a course in electrical engineering for non-EE students. In addition, Truxal has been a frequent author of technical papers at IRE and AIEE sessions.

When he was made head of the EE Department at Brooklyn Poly in 1957, Truxal had a chance to try out some of his educational ideas. For example, he believes that no one person builds a school's curriculum. What

he tries to do is create an atmosphere that encourages all faculty members to experiment. It means that Brooklyn Poly's EE Department rarely teaches a course the same way twice.

Truxal also believes strongly that university faculties must conduct research or risk getting out of touch with practical engineering. He devotes almost 50 percent of his time to research. Right now he's working on a government contract on adaptive control systems (controls that change their characteristics with changes in environment), and he serves as a control consultant for such companies as RCA and Airborne Instruments.

The work on adaptive controls has struck a particularly responsive note with Truxal. First off, it is brand new. But even more important, as Truxal says, "The real vision is to build a control system that behaves like a human being." With the adaptive principle engineers can finally envision building machines to do complicated tasks that only humans could do previously.

His work as researcher, administrator, teacher, and author build a ten- to twelve-hour day for Truxal. This year his work load grew even heavier when he was elected chairman of the Feedback Controls Committee of the AIEE. And he's chairman of the control theory program committee for U. S. papers for the 1960 IFAC meeting in Moscow. His main outlet for recreation is travel (he doesn't count his daily commuting trips from Long Island in this category), when he can pile the family into the car and take off for points of interest in the United States. His frequent trips have convinced him of the constant demand for changes in the control field. He tries to keep the same need for change at Brooklyn Poly, creating an environment that stimulates the imaginations of faculty and students.

*Published by McGraw-Hill Book Co., Inc., New York, N. Y.

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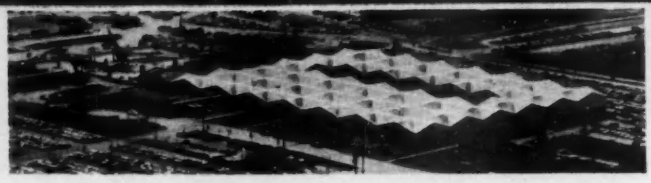
100% test of the performance and uniformity built into TI 'mesa' units is conducted automatically by CAT—Centralized Automatic Test equipments. Designed and built by TI, these machines each have a capacity of 40,000 units a day.



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2N697 MULTI-PURPOSE SILICON 'MESAS' NOW MASS-PRODUCED BY WORLD'S LARGEST TRANSISTOR MANUFACTURER

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FEATURE:

- **Diffused-base 'mesa' construction**
- **2-w maximum power dissipation at 25°C**
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Available now in production quantities ... TI 2N696 and TI 2N697 multi-purpose silicon 'mesa' units for amplifier, switching and medium-power applications.

Produced by the pioneer of the diffused-base process, these highly reliable 'mesa' units feature... *2-w maximum power dissipation... beta spreads of 20-60 (TI 2N696) and 40-120 (TI 2N697)... 10-ohm maximum saturation resistance.*

Your full-year guarantee is backed by TI's proven production capabilities (largest in the world and currently being doubled) and a stringent quality assurance program.

Check these specs and contact your nearest distributor or TI sales office for *immediate* delivery.

electrical characteristics at 25°C ambient

(unless otherwise noted)

	PARAMETERS	TEST CONDITIONS			min.	max.	unit
I_{CBO}	Collector Reverse Current	V_{CB} = 30v	I_E = 0		—	1.0	μa
	at 150°C	V_{CB} = 30v	I_E = 0		—	100	μa
BV_{CBO}	Collector-Base Breakdown Voltage	I_{CBO} = 100μa	I_E = 0		60	—	v
BV_{CER}	Collector-Emitter Breakdown Voltage	I_{CER} = 100ma	R_{BE} = 10 ohms		40	—	v
BV_{EBO}	Emitter-Base Breakdown Voltage	I_{EBO} = 100μa	I_C = 0		5	—	v
h_{FE}*	D-C Forward Current Transfer Ratio	I_C = 150ma	V_{CE} = 10 v	(2N696)	20	60	—
				(2N697)	40	120	—
$V_{BE\,(sat)}$*	Base-Emitter Saturation Voltage	I_C = 150ma	I_B = 15ma		—	1.3	v
$V_{CE\,(sat)}$*	Collector-Emitter Saturation Voltage	I_C = 150ma	I_B = 15ma		—	1.5	v
h_{fe}	A-C Common Emitter Forward Current Transfer Ratio	I_C = 50ma	V_C = 10v	f = 20mc	2.5	—	—
C_{ob}	Collector Capacitance	I_E = 0ma	V_C = 10v		—	35	μμf

*Pulse conditions: length = 300μs; duty cycle < 2%.

maximum ratings at 25°C ambient

Collector-Base Voltage	60v
Collector-Emitter Voltage (R_{BE} = 10 Ω)	40v
Emitter-Base Voltage	5v
Total Device Dissipation	0.6w
Total Device Dissipation at case temperature 25°C	2w
Storage Temperature Range	−65°C to +175°C

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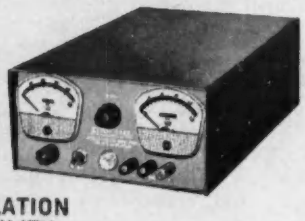

Model SC-18-2M

0.1% REGULATION STABILITY

MODEL	DC OUTPUT VOLTS	DC OUTPUT AMPS.
SC-18-0.5	0-18	0-0.5
SC-18-1	0-18	0-1
SC-18-2	0-18	0-2
SC-18-4	0-18	0-4
SC-36-0.5	0-36	0-0.5
SC-36-1	0-36	0-1
SC-36-2	0-36	0-2
SC-3672-0.5	36-72	0-0.5
SC-3672-1	36-72	0-1

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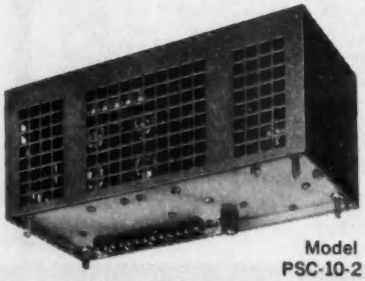

Model PSC-10-2

0.01% REGULATION STABILITY

MODEL	DC OUTPUT VOLTS	DC OUTPUT AMPS.
SC-32-0.5	0-32	0-0.5
SC-32-1	0-32	0-1
SC-32-1.5	0-32	0-1.5
2SC-32-1.5	0-32	0-1.5
DUAL OUTPUT	0-32	0-1.5
SC-32-2.5	0-32	0-2.5
SC-32-5	0-32	0-5
SC-32-10	0-32	0-10
SC-32-15	0-32	0-15
SC-60-2	0-60	0-2
SC-60-5	0-60	0-5
2SC-100-0.2	0-100	0-0.2
DUAL OUTPUT	0-100	0-0.2
SC-150-1	0-150	0-1
SC-300-1	0-300	0-1

0.02% REGULATION STABILITY

COMPACT PACKAGE TYPE

MODEL	DC OUTPUT VOLTS	DC OUTPUT AMPS.
PSC- 5-2	0- 7.5	2
PSC-10-2	7.5-12.5	2
PSC-15-2	12.5-17.5	2
PSC-20-2	17.5-22.5	2
PSC-28-1	22.5-32.5	1
PSC-38-1	32.5-42.5	1

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Newsbreaks In Control

GE OFFERS SERVICE POLICY ON NUMERICAL CONTROL

Waynesboro, Va.—General Electric Co.'s Specialty Control Dept. is readying the first service policy for numerical-controlled equipment ever offered. Users of GE numerical control will be able to buy the policy for $500 or $600 (definite price has not yet been fixed). The policy will guarantee all parts for one year, will provide preventative maintenance by a GE service man on a regular schedule, and will assure the appearance of a GE service man within 24 hours of a report of trouble.

BECKMAN TO SET UP COMPUTER-CONTROLLED PILOT PLANT

Fullerton, Calif.—Scientific and Process Instruments Div. of Beckman Instruments is setting up a small pilot plant involving a continuous distillation operation to study the impact of end-point analyzers and computers on control. The fabrication tower will be equipped with conventional control instrumentation—liquid level, flow, temperature—and a multistream gas chromatograph. Throughput and purity data will be obtained under conventional control and compared to similar data obtained when the tower is run under cascade control from the gas chromatograph. Next, an analog computer will direct control, and then digital techniques will be applied.

AIR TRAFFIC CONTROL COMPUTER READIED

Atlantic City, N. J.—Federal Aviation Agency engineers are ready to receive for test and evaluation the first special purpose digital computer built for air traffic control. The unit, built by Librascope, will fit into an air traffic control system proposed by the General Precision Laboratories (a sister division of Librascope in General Precision Equipment Corp.). The computer will receive information concerning the speed, destination, and route of air traffic; determine if conflicts exist; print out flight strips for each aircraft for each check point; and report conflicts. Results of the evaluation will be anxiously eyed; some experts have questioned the GPL approach (CtE, Jan. '59, p. 22) because of its continued reliance on flight strips.

ECS UNWRAPS TAPE-CONTROLLED PRODUCTION INSPECTOR

Los Angeles—Electronic Control Systems, a div. of Stromberg-Carlson, has built a prototype of a semiautomatic, tape-controlled machine, designed to inspect close tolerance parts. Company expects the unit to find major application in locations ranging from job shops to on-line production in aircraft and missile plants. Initial units will be equipped with two-axis control and manual readout, should sell for about $22,500. Next step: a three-axis model with automatic strip chart readout to sell for $30,000.

ACOUSTIC CONTROLS GAIN NEW ATTENTION

Los Angeles, Calif.—Hottest subject these days in missile control is the application of sonic controls (actually ultrasonic frequencies) to produce vibrations which change the burning rate of fuel in solid propellant rockets. Aerojet-General and Acoustica Associates have a joint development program underway for the National Aeronautics and Space Agency. But at least one ultrasonics specialist, H. E. McKenna of McKenna Laboratories, sees a big potential for acoustic controls in the wet process chemical industries. For example, he says ultrasonics can reduce the time for catalytic cracking to one-tenth of that now required.

JAPANESE ENTRY
Transistorized recorders were displayed by Tokyo Shibaura Electric Co. If U.S. interest is sufficient, the Japanese company will begin exporting a complete line of transistorized instruments, will establish service and spare parts facilities in the U.S.

LINEAR ACTUATOR
Newest addition to line of controls made by General Controls is this linear actuator, a gear unit powered by an electric motor. Linear action stems from ball screw drive.

A Control Engineer's

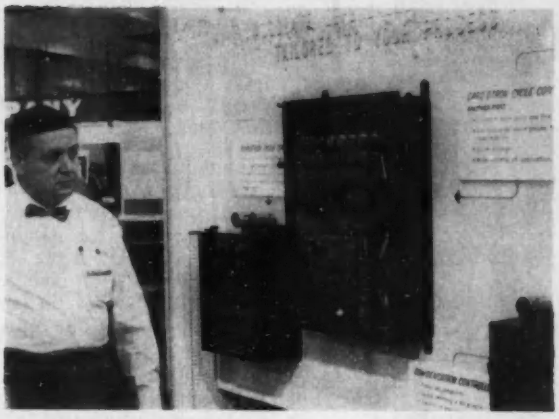
The Windy City hosted the instrument and control industry during a hectic round of activities that included an executive meeting of IFAC (page 30), the annual ISA conference and exhibit (see story below), FIER's first Distinguished Lecture (page 35), and a significant, highly unusual meeting on computing-control (page 36).

CHICAGO—In Chicago's sweltering International Amphitheatre, almost 25,000 control engineers toured the biggest (in size) Instrument-Automation Exhibit ever sponsored by the Instrument Society of America, from September 21 to 25. Most visitors agreed it was a solidly based show, covering hardware from measurement to actuation. But the exhibits emphasized improvement rather than innovation. Any visitor looking for a repetition of the 1958 show, when a large number of radically new products were unveiled, suffered somewhat of a disappointment.

At almost every booth, products displayed the mark of the improvement trend: at one booth it was higher frequency response; at another, booth attendants pointed out a direct readout added to a well established line of laboratory instruments; and many exhibitors were stressing that prototypes prematurely rushed from the research laboratory to last year's show were now commercially available.

Although there were few significantly new products on display, visitors found no shortage of material for conversations with shirt-sleeved booth attendants. Probably the subject of most conversations was computing-control and how fast it was moving. Almost everybody in the computer-for-process-control business had at least one installation or one sale to talk about.

• **More computing-control**—And new ones kept turning up. For example, on the first day of the show, Philco and Leeds & Northrup announced the first sale of the computer they have been jointly developing. The machine, a LN 3000, will be delivered next sum-



CARD PROGRAMMER
Punched card control of sequenced process operations is made possible by new Card-O-Tron, developed by Taylor-Emmet Control Co., a div. of Taylor Instrument Cos.

PUSH BUTTON TRANSFER
New electric control system unveiled by Bailey Meter Co. in a display which compared push-button hand-auto transfer to conventional hand-auto transfer.

ELECTRONIC VISCOMETER
Viscomparator, shown by Bendix Aviation Corp., measures and controls viscosity directly, comparing process fluid with a reference sample.

Busy Week in Chicago

mer to Public Service Electric & Gas Co. of New Jersey, which will calculate operating guides for station operators with the machine, may eventually perform closed-loop control of boilers with it. At a special meeting on Tuesday, The Foxboro Co. and Radio Corporation of America announced joint plans for marketing RCA's new 110 computer to the process industries.

Computing-control managed to work itself into almost every technical session that included a mention of computers for data processing, bringing out clearly the keen interest in the subject. One frequent topic was the problem devised by users' engineers to compare the approaches of computer manufacturers (see page 36).

Despite the tremendous enthusiasm, there was still plenty of doubt expressed. One utility engineer, for example, felt that computer-control of automatic startup of generating units would prove premature at this time; he said successful computer startup was probably three or four years away—even though a couple of automatic startup projects are already underway. A chemical process control engineer expressed the opinion that clever use of on-line analysis instruments might bring about bigger savings than computing-control in many processes, with a much smaller capital investment. The crux of computing-control still remains indecisive, most people agreed. Still unanswered is the big question, will it pay off economically?

But the enthusiasts far outweighed the doubters. And rumors at the show had at least three U. S. companies entering the field with new real-time, on-line computers over the next 12 months: IBM (which had been thought to have a machine ready for this year's show), Minneapolis-Honeywell, and Westinghouse Electric Corp.

• **Japan eyes instrument markets**—From a marketing standpoint, probably the key innovation at the show was the display of Japanese instruments by two Japanese companies. The Yokogawa Electric Works Ltd., an associate of The Foxboro Co., showed off a line of laboratory instruments: precision ammeters, voltmeters, and high frequency milliammeters. Across the Amphitheatre, Tokyo Shibaura Electric Co. Ltd., partially owned by the General Electric Co., displayed a line of fully transistorized electronic recorders.

Sensing U. S. concern about the Japanese instruments, Dr. Shunzo

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Size 15	15M10A4	1.45 „	3300	—
Size 11	11M10A10	0.63 „	3300	—
Motor Tachometer				
Size 18	18M10D6	3.5 oz. in.	3000	1.25
Size 15	15M10B8	1.45 „	3000	1.25
Size 11	11M10E1	0.6 „	3200	0.2

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WHAT'S NEW

Busy Week in Chicago—ISA

Imai, manager of Toshiba's Instrumentation and Automation Division, held a press conference to advise that "imports of Japanese electronic equipment are not a threat to U. S. national security." Dr. Imai attacked the suggestion, made by the Electronic Industries Association earlier in the week, to revise the U. S. Trade Agreements Extension Act, which encouraged Japanese imports.

But U. S. design engineers, scrutinizing the Japanese equipment with more than curiosity, were not so sure. They reported that the Japanese instruments were high quality, some apparently copies of U. S. designs. And the engineers estimated that the Japanese designs could probably sell at prices 30 to 40 percent lower than U. S.-made equivalent instruments.

At the Toshiba booth, an attendant told CtE that the display was really just a trial balloon, to see how U. S. users would react to foreign instruments. If real interest developed, the Japanese representative said, Toshiba was ready to start selling. The company already exports almost 40,000 transistorized radios a year to the U. S. It has repair and spare parts facilities in New York and Chicago to service the radios. If the company decides to export instruments too, it will expand its present service facilities and open a new one on the west coast.

• **A pill for manufacturers**—Still another problem for manufacturers was ISA's plans to increase the number of shows to three a year in 1960, and four a year thereafter. After an apparent first approval, a number of exhibitors were developing misgivings. Most felt they would probably be forced by competition to exhibit at all shows, but they would keep their show budgets the same. That would mean smaller booths, manned primarily by regional sales people.

The show schedule for next year: Houston, February 1 to 4; San Francisco, May 9 to 12; and New York, September 26 to 30.

• **Product innovations**—The product innovations at the show were a cross-section of hardware used by control engineers. No single trend predominated. Some typical new devices:

► A new system of electric control displayed by Bailey Meter Co. All solid-state, using transistors and magnetic amplifiers, the new system's most unusual capability is automatic transfer from manual to automatic control, even without an operator being pres-

ent. Unattended transfer may be originated by signals from a sequencing system or by predetermined high or low signals from a standard transducer. Control signal range is minus 25 to plus 25 vdc. Installations have already been sold to a utility and to a steel company which will control a soaking pit with it. In the next year Bailey expects its electric system to cost 30 percent more than its pneumatic equivalent; the company anticipates system sales will run 90 percent pneumatic, 10 percent electric.

▶A radiation bolometer, also displayed by Bailey Meter, with a higher output and increased sensitivity. Simpler than a dc device, the Bailey Bolometer is an ac device in a wheatstone bridge circuit. It can measure up to 4,000 deg F with plus or minus 1 percent accuracy. A major advantage claimed for the new device: its capability does not deteriorate with use.

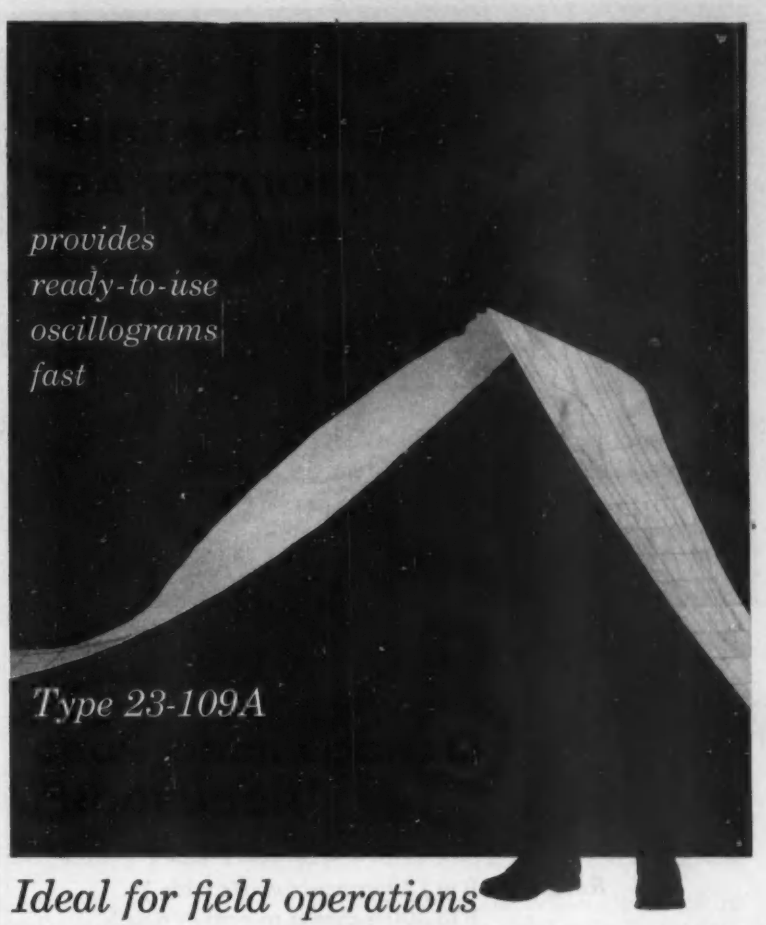
▶New linear actuator made by General Controls is a gear unit powered by an electric motor. Rotation of a ball screw drive imparts linear action to the driven shaft. By adding a feedback or position-transmitting potentiometer, a user can operate unit with proportional control systems or can obtain position indications at remote operating points.

▶New optical aid for landing aircraft built by Decker Corp. is now being tested by Federal Aviation Agency. The device with a white light center has a collimated light beam divided into four differently colored quadrants. A pilot making a landing on the correct glide path would see the white light. If he were too low, he would see red; too high, green; too far right, blue; and too far left, yellow.

▶New Viscomparator by Bendix Aircraft Co. controls viscosity in processes. It measures and controls viscosity directly and continuously by comparing the process fluid with a standard sample immersed in the process stream so it is at process temperature. Because control action is based on the viscosity of the standard sample, the device is said to produce proper viscosity-blended products independent of process temperature.

▶New Oscar, semi-automatic device for reading photographs and oscillographs, built by Benson-Lehner is contained in a single console; former models had a separate cabinet for digitizer and other accessory equipment. New unit sells for under $5,000. Benson-Lehner also showed off an artist's conception of its new magnetic tape converter, which will also be repackaged for compactness.

▶Punched card programmer for sequencing batch process operations was displayed by Taylor-Emmet Controls,



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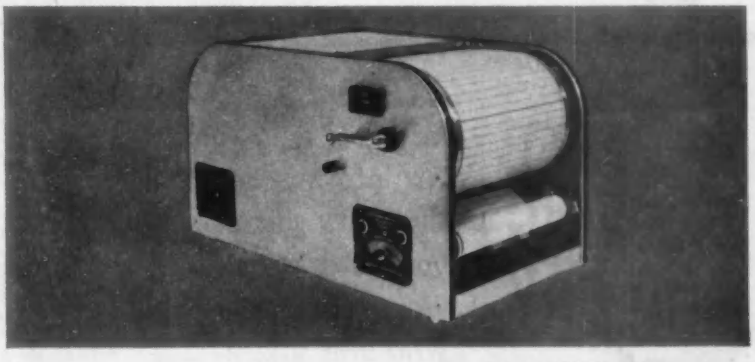

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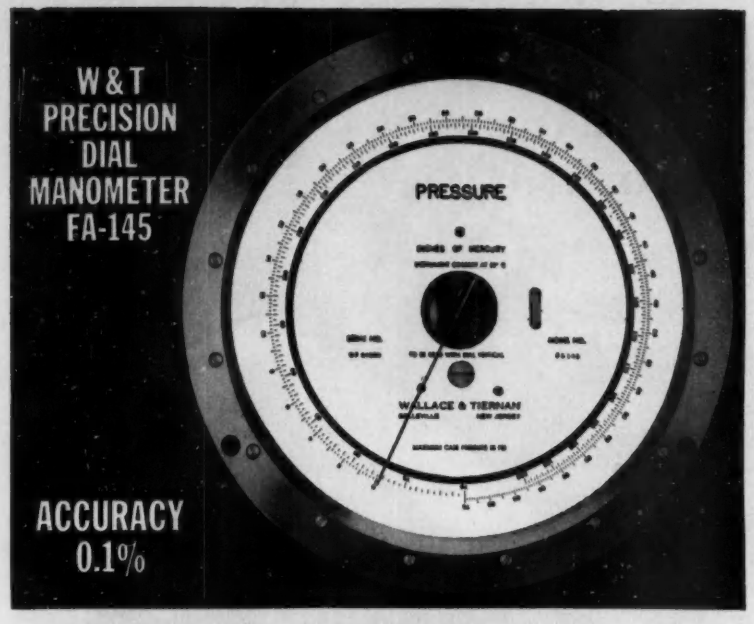
CIRCLE 25 ON READER SERVICE CARD 25



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WHAT'S NEW

Busy Week in Chicago—ISA

Inc., in the Taylor Instrument Cos.' booth. It is called Card-O-Tron. The device, programmed by a Mylar punched card, can handle up to 20 circuits (a new model soon to be announced will handle up to 30). The new Card-O-Tron replaces a unit which had a pushbutton keyboard. By using a punched card for programming instead of the keyboards, Taylor-Emmet was able to reduce the size of the unit significantly (a 20-circuit, pushbutton programmed control would be five or six times larger). Another big advantage of card programming is the ease with which a setup can be changed. And the card can be retained as a record of a particular batch, which can be duplicated merely by using the same card for programming. The 20-circuit Card-O-Tron costs about $1,800.

• **In the sessions**—ISA's technical session program was one of the most comprehensive since the society was formed. This year the society encouraged the preparation of papers stressing general approaches rather than detailed hardware articles, and interest was broader.

The Aeronautical Instrumentation Session was a good example. L. R. Chapman, General Precision Laboratory, described the instrumentation incorporated in aircraft to obtain meteorological data, particularly information about big storms. The aircraft (a DC-6 and a B-47) carrying a variety of instruments and data processing equipment were flown through violent storms for periods as long as seven and eight hours, gathering data on wind, pressure, humidity, and temperature.

J. Stotz, Grumman Aircraft Engineering Corp., discussed two interesting jobs done by flight instrumentation. One was the study of human-like dummies which were ejected from aircraft at ground level, the other was an analysis of spin. Instrumentation in both cases was heavily photographic. Stotz's presentation was highlighted by some extraordinary movies taken of both testing operations.

Finally, Dr. R. L. Howland of Lockheed Aircraft expressed some strong views on the status of operational aircraft instrumentation. His opinion: progress is sad. Howland pointed out that today's pilot has an airspeed indicator, which doesn't tell him how fast he is going; an outside air temperature thermometer, which doesn't tell him how cold it is; and an altimeter, which doesn't tell him how high he is. He

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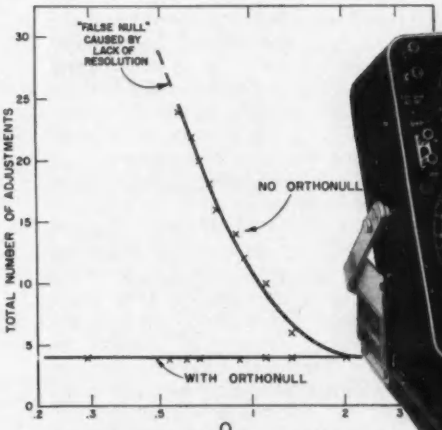
The Orthonull* mechanism is an exclusive feature of G-R's new Impedance Bridge. Orthonull eliminates the annoying "sliding balance" that is common when measuring components having high losses with bridges that operate in the conventional nonorthogonal coordinate system. Basically, Orthonull makes the normally interdependent C, R, or L, and D (or Q) adjustments independent by making use of a unique unilateral ganging mechanism. With Orthonull engaged, adjustment of the CRL dial adjusts the DQ dial as well, cancelling electrical interdependence. Once the bridge is "locked on", convergence of the two adjustments becomes rapid, adjustment procedure is greatly simplified, and the danger of balancing to a false null is eliminated.



Plot shows the number of adjustments necessary to balance the bridge within 1% for a given Q with and without Orthonull.

*Patent No. 2,872,639

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WHAT'S NEW

Busy Week in Chicago—ISA

gave three reasons for the present situation: 1) airframe manufacturers haven't told instrument makers what is needed; 2) customers, both government military services and commercial airlines, dictate what goes into the cockpit, frequently base a choice on prejudice rather than engineering; and 3) instrument makers with new devices and new ideas don't know whether to try and sell their new approaches to the customer or the airframe builder.

• **What makes companies run**—Interest in the management aspects of control seemed on the rise too. Last year, only 15 hardy listeners turned up at a session on economics and management. This year, almost 200 engineers crowded into one session to hear CtE's B. K. Ledgerwood discuss how Control Systems Engineering can be used by management, General Motors' A. F. Welch and R. V. Fisher discuss the organization needed to solve instrumentation problems today and Monsanto Chemical Co.'s C. L. Parish estimate personnel needs for tomorrow's instrumentation.

This session hit hard an area which was a source of a lot of conversation at both the show and sessions. A lot of visitors were asking questions like these: What kind of organization is needed to do a systems job? What kind of people are needed in such an organization? And where does a company find such people.

Almost 75 listeners at another economic and management session on Economic Justification heard G. W. Baughman, Westinghouse Air Brake Co., report that railroads had reduced damage claims 85 percent by using automatic classification equipment and automatic speed retarders in classification yards. A number of railroads reported returns on investment in such automatic equipment running over twenty percent.

Peter Nolle of Riverside Cement Co. described the economic reasoning behind the installation of an RW-300 computer at the Oro Grande works of Riverside. The machine will compute the proper blending of materials to obtain the most economic mix in 35,000-ton batches. Since the company has invested almost $1 in labor and overhead to move each ton of materials in the batch, and three or four batches are made each week, Nolle says the computer should pay for itself easily by preventing mistakes in batch making.

—The Editors

HOW MANY DROPS MAKE A LEAK?

Front Panel — Electrical Control Assembly

All-New CI LEAKMETER *Automatically Measures Hydraulic or Fuel Leakage!*

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Operation of the LEAKMETER is automatic with a built-in timer which can be set for periods of 15 seconds to 5 minutes, providing a range for the instrument of 0.008 to 80 cc per minute. To measure other rates of leakage, or to test for sustained zero leakage, the timer may be overridden and the test conducted over any desired period.

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Front Panel — Hydraulic Transducer Assembly

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In A U. S. Engineer's Basement . . .

. . . IFAC's President Listens

Dr. A. Letov, deputy director of Russia's Institute of Automatics and Telemechanics listens to Gary Boyd describe the workings of transistorized computer synchronization circuit. Gary is one of a group of Hinsdale High School students who have been studying computer technology under Gary's father, Universal Oil Products' David Boyd.

. . . Ukranian Specialist Watches

A. G. Ivaknenko, Electro-Technical Institute, Kiev, Ukraine, looks over the test bench setup used by high school students Dave Lescohies (seated) and Carl Ellison (standing) in their evening computer studies in Dave Boyd's basement. Equipment has been contributed to the study group by many U. S. companies.

BUSY WEEK IN CHICAGO

IFAC Works and Plays, American-Style

IFAC, The International Federation of Automatic Control entertained a full agenda of serious professional interests at its general assembly, held at Chicago's famous Edgewater Beach Hotel. Delegates (and proxies) representing the 22 national member organizations elected officers for the next two years, ratified a brand new constitution, and heard that Yugoslavia, Australia, Canada, and Spain will soon join the Federation. Drawing a second wind, the session approved plans of technical committees and discussed the preparations being made by the USSR National Committee of Automatic Control for the first IFAC congress next June. But once the serious matters were disposed of, the delegates were exposed to two American recreational institutions: the cocktail party and the cookout.

To the Russian and Hungarian delegates, the cocktail party at the home of Northwestern University Professor R. W. Jones, and the cookout in the backyard of Universal Oil Products' chief instrument engineer, D. M. Boyd, supplied pictures of how U.S. educators and engineers live.

After mastering corn-on-the-cob—and how to eat it, the foreign delegates were intrigued by the extent to which engineer Dave Boyd's vocation is reflected in his hobbies. They oh'ed at his orchids, growing in a greenhouse equipped with an automatically controlled atmosphere, and beamed at a home-built digital computer that calculates and displays the average road speed of his Mercedes sports car (and whose efficiency is evidenced by the number of cups and ribbons won in sports car rallies).

But the most impressive display was

If You Are Going to IFAC's Congress . . .

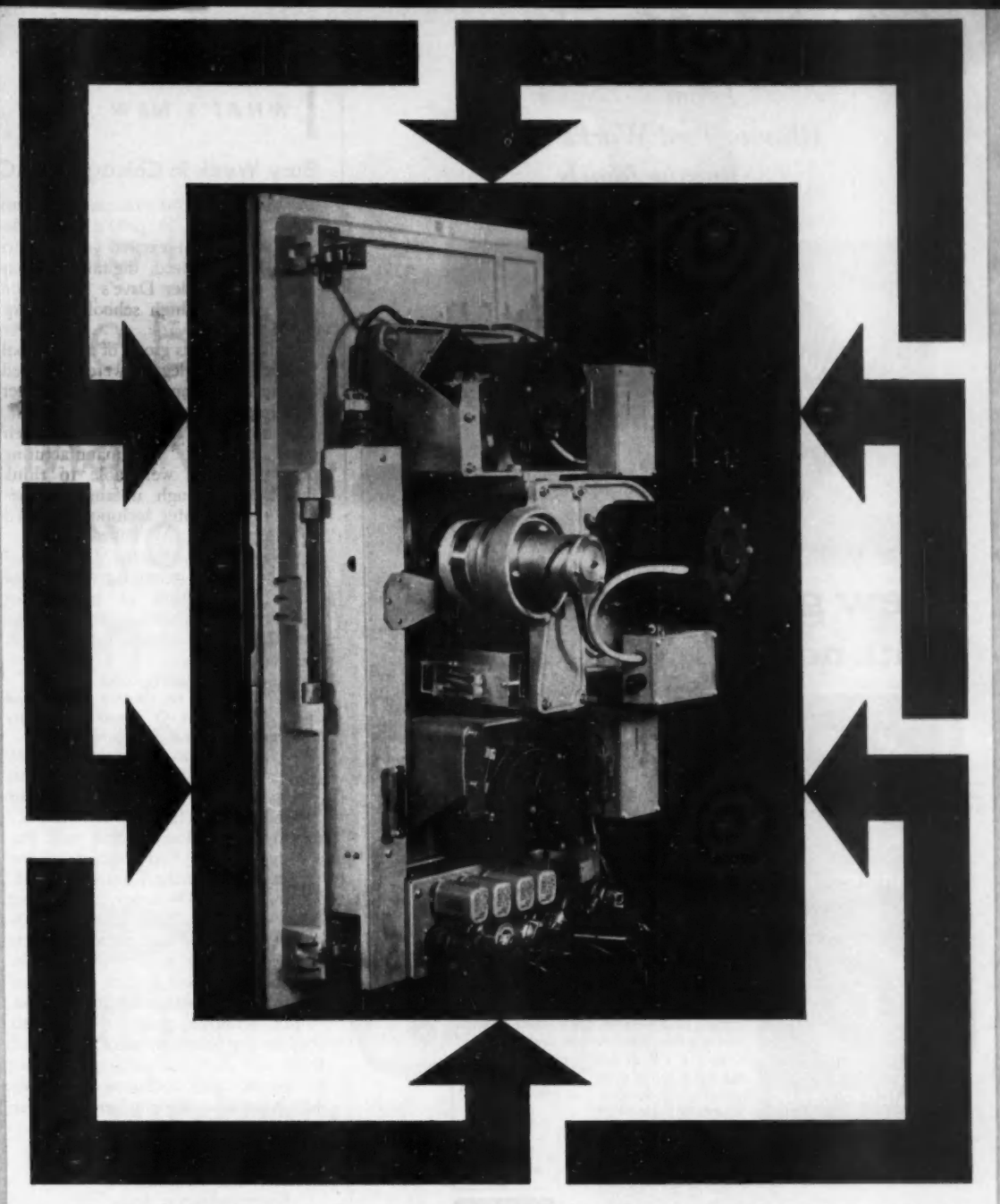
For information on arrangements for attendance at First IFAC Congress, Moscow, USSR, June 27—July 8, 1960 Write:

Secretary, American Automatic Control Council (Editor, CONTROL ENGINEERING) 330 W. 42nd St., N.Y. 36, N.Y.

Inform the secretary of your plans to attend the Congress by the first week in February. AACC needs your full name, title, place of work, and address so that it may assemble for IFAC a complete list of people who will attend from the USA. Congress registration will cost those who are not presenting papers $20 before Mar. 31 and $30 afterward. Authors may register for $15 before that date and for $20 later.

Registration paid in advance of Mar. 31 will entitle you to a full set of preprints in English. Buttersworth Scientific Publications, the proceedings publisher, will distribute the preprints sometime in April.

Intourist, the Soviet tourist agency, will handle all travel and accommodations within USSR. Registrants may select any of these Intourist rates: Deluxe, $30 per day; First Class, $18 per day; Tourist A, $12 per day; Tourist B, $10 per day.



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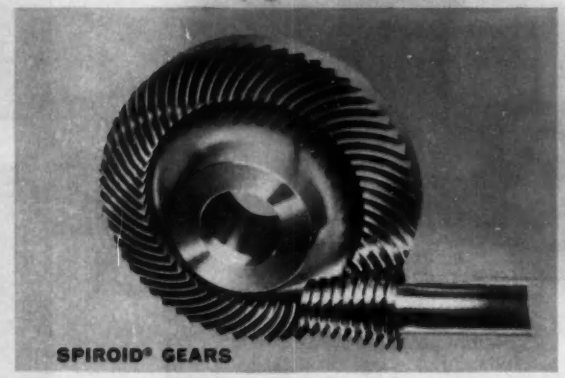

new gear economies
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WHAT'S NEW

Busy Week in Chicago—IFAC

to be seen in Boyd's famous basement (CtE, October '54, p 11). The delegates were most excited by a home-made transistorized, digital computer being built under Dave's supervision by a group of high school boys (see p 101).

Talking to this group of after-school tinkerers, the delegates were impressed by the boys' knowledge of computer principles and of circuit manufacture. The boys who had developed their own technique of manufacturing printed circuits were able to think their way through unfamiliar questions on computer techniques, posed by the visiting IFAC delegates.

• **New IFAC officers**—Most serious business of the general assembly had been the election of officers for 1960-61. The slate prepared for the assembly was unanimously elected. The new officers:

President, A. M. Letov, USSR
1st Vice President, Ed. Gericke, Switzerland
2nd Vice President, O. Benedikt, Hungary
Secretary, G. Ruppel, Germany

• **Moscow plans**—Since its organization last year, IFAC has directed its technical efforts primarily towards its first congress, scheduled for June 27 to July 3, in Moscow next year. Reporting for the USSR National Committee of Automatic Control, host for the conference, Dr. Letov, advised that 321 authors who had submitted abstracts had been invited to complete their papers for final selection. The Soviet hosts expect to pick about two-thirds of that number for presentation.

The tentative program allows six days for the presentation of papers and three full days for prearranged visits to plants and technical institutes. The program with number of papers:

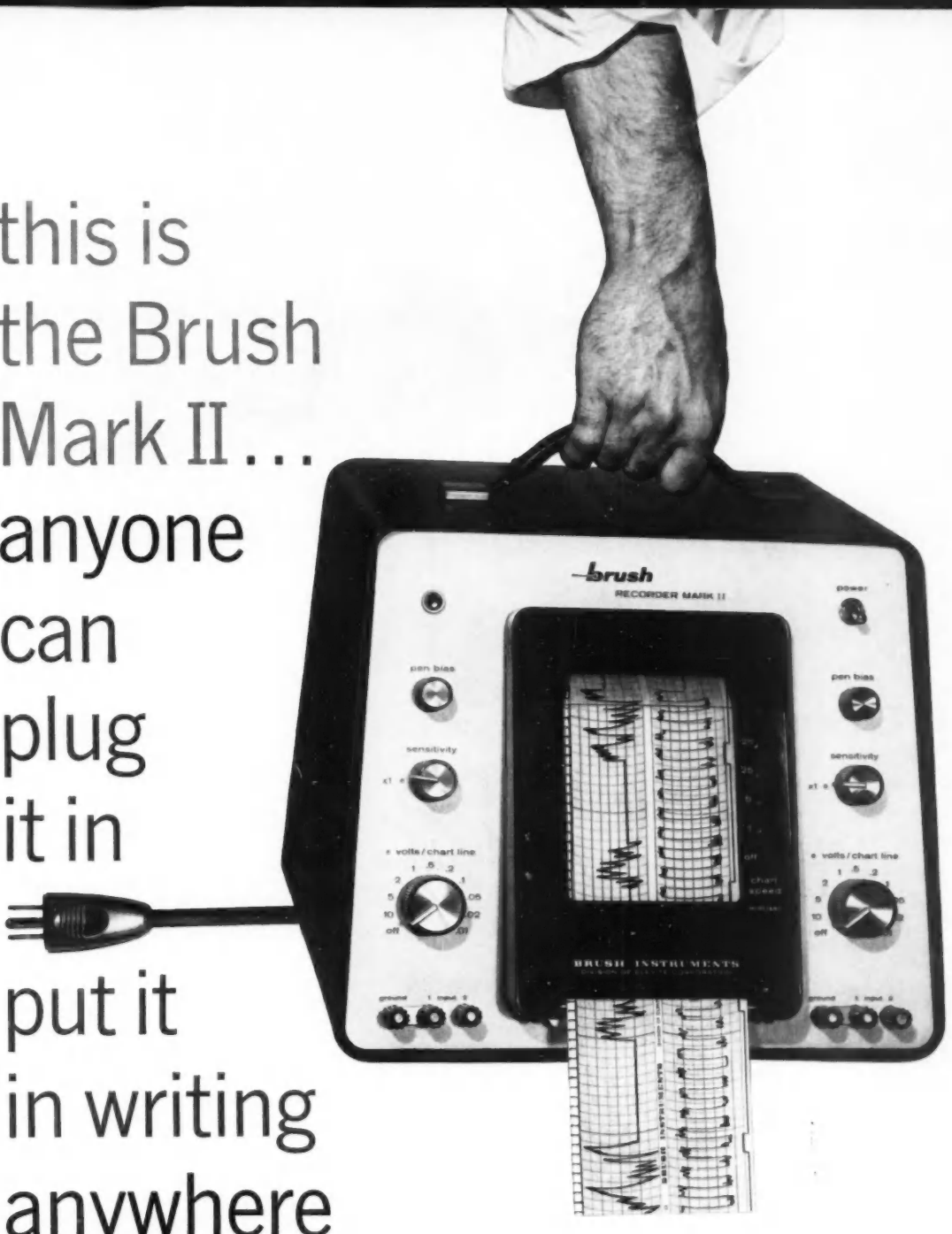
Section I. Theory
- Continuous systems (38)
- Discrete systems (18)
- Stochastic problems (18)
- Optimum system design (22)
- Self-adaptive Systems (13)
- Remote control (5)
- Problems in mathematics (27)

Section II. Components
- Electric and magnetic elements (13)
- Computing, programming devices (20)
- Centralized control and telemetry (10)
- Electric final control elements (9)
- Pneumatic transducers, systems (13)
- Pneumatic computers (6)

Section III. Application
- Machine building (8)
- Power and heat systems (16)
- Chemical and oil refining (16)
- Electric drives (12)
- Continuous processes (14)
- Nonclassified problems (52)

—William E. Vannah

this is the Brush Mark II... anyone can plug it in put it in writing anywhere



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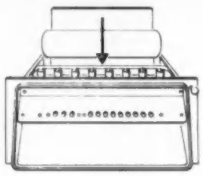
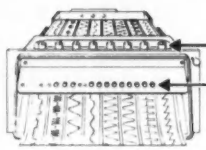
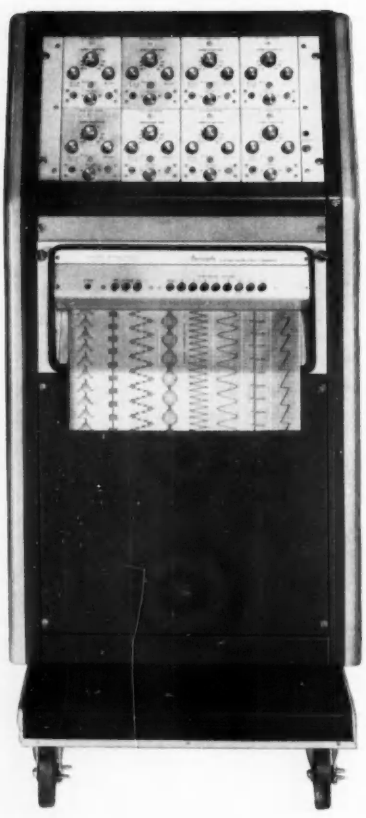


Chart paper loads from top



Trace contrast control

Simple pushbutton speed selection



Why? Simply because Brush recording systems such as this 6-8 channel unit incorporate all of the known refinements in the art of recording by direct writing. No comparable system in existence today is as compact . . . as simplified . . . as reliable . . . as versatile. Note slide-mounted oscillograph and interchangeable "plug-in" signal conditioners that provide four vital functions in addition to amplification: high input impedance, zero suppression, attenuation and calibration.

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CtE's Publisher W. W. Garey, retiring President of FIER, starts off the first Distinguished Lecture. Also at the head table: G. F. Metcalf, vice-president, General Electric Co., who introduced the speaker, Dr. M. P. O'Brien who offered a new approach to training engineers in advanced areas of technology, and A. F. Sperry, president of Panellit Co., FIER's 1960 president.

BUSY WEEK IN CHICAGO

FIER Speaker Urges A Return to Design

At Chicago's University Club, a select group of about 25 leaders in instrument business and education settled back to hear a new phenomenon in the instrument industry, the Distinguished Lecture sponsored by the Foundation for Instrumentation Education and Research. FIER's first speaker, hard-talking Murrough P. O'Brien, who had retired as Dean of Engineering at the University of California last June, soon had his audience on the edge of their chairs as he pulled no punches in presenting how he thought engineers should be trained for advanced areas of technology.

As a starter, Dr. O'Brien lamented that engineering schools have lost their way. Engineering faculties, he said, have lost touch with the engineering profession. They think that a knowledge of science and mathematics can solve problems. Since he defined the key to engineering as design, the conception of doing a job, he feels strongly that an emphasis on mathematics and science in engineering curriculum is no substitute for practical knowledge.

After decrying how engineers for new technologies were being trained, Dr. O'Brien offered his own program. He was not enthusiastic about setting up formal curricula in specific areas like instrumentation engineering. He feels it sets up artificial barriers and it takes too long. "By the time the curricula are formalized, there is no longer a real need for engineers in the advanced area. When we really need these people is when the technology is brand new."

• **Speaker's program**—O'Brien would prefer to train well-rounded engineers who have specialized in design. The new technology, he feels, can be introduced in one or two formal courses. Here are the main points in his program for training engineers for advanced technologies:

▶ Master's program should be the absolute minimum.

▶ Creative design should start in the freshman year, should continue throughout the course.

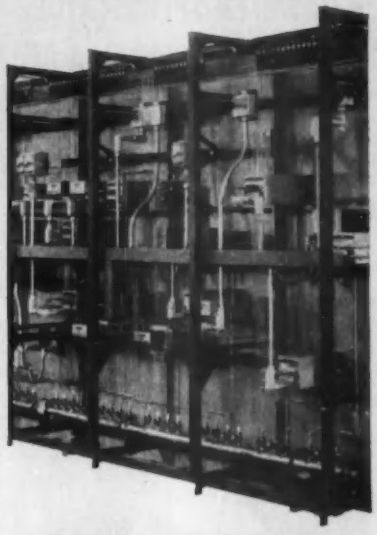
▶ Intensive experimentation should be a part of the course, experimentation in which the student is encouraged to strike out on his own rather than following today's canned experiments in a cookbook fashion.

▶ A final examination should measure the student's ability to design as opposed to a measure of piecemeal competence in a lot of subjects. Such an exam would measure the student's integrated understanding of and capability in engineering.

▶ Cooperative education – alternate periods of work and study—is the best way to achieve a practical background.

▶ Courses specializing in specific areas of technology should be offered as electives. —LHY

NEW!



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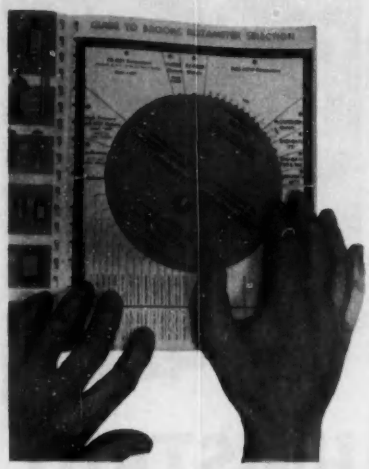

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Generalized Problem Stirs Up Computing-Control

An unpublicized meeting to discuss a method of comparing computers for process control generated the most spectacular fireworks of the week.

How can you compare the various computers being offered by manufacturers for process control? Users trying to answer that question have launched an unusual project in which they have asked computer manufacturers to solve a generalized problem with their various equipments and approaches. Although the purpose is to determine what type of computer best fits various control applications, the results could well freeze the future of many of the entries in the computing-control field. A good solution to the general problem might win a favored position for a fortunate manufacturer, a poor one might damage the marketing plans of an unlucky maker.

That's why a little publicized meeting held after the windup of the ISA show looms so important. Over 50 representatives of users and makers of computers for control gathered at the invitation of the AIEE Subcommittee on Computer Systems in the cafeteria of the Panellit Co.'s Skokie (Ill.) plant. Stripped to their shirt-sleeves, the engineers probed the pros and cons of the generalized problem.

It all started last May when a group of members of the American Institute of Chemical Engineers were trying to compare various computers offered commercially for process control. Monsanto's T. J. Williams suggested preparing a typical problem which all the manufacturers could solve. The idea was passed along to the AIEE, and that group's Digital Computer Subcommittee, chairmanned by Philco's Gary Hollander, jumped at the suggestion. Hollander offered to let manufacturers (and others who so desired) present solutions to the problem as technical papers at the subcommittee's sessions during the annual winter meeting of AIEE in New York. Special sessions for this purpose were set up by the AIEE's Computer Systems Subcommittee, of which the Digital Computer group is a part.

Monsanto Chemical Co.'s analytical section, headed by Dr. Theodore Williams, then synthesized a general problem, which was distributed to interested parties, both manufacturers and users. Purpose of the Skokie meeting was to have a person-to-person discussion of the AIEE problem and procedures for presenting the papers.

• **The AIEE problem**—Although the generalized problem does not have an actual commercial counterpart, it does include units and operations familiar to chemical processes and plants. Feed streams enter a stirred tank reactor, then pass to a reaction-cooler heat exchanger, on to a decanter, and finally into a distillation column. Various disturbances are introduced into the process, such as variations in flow and annual and daily variations in the temperature of the cooling water.

In introducing the problem, Dr. Williams stated three objectives of solutions to the fictional process: 1) to show how to add a computer and necessary instrumentation to the process, 2) to figure the cost of this added equipment, and 3) to measure the economic improvement of operation and the corresponding return on investment. While the problem is primarily a technical one in systems engineering, the computing control solution was to be judged solely on payout.

• **Users view**—At this point, differences of opinion appeared, almost as many as there were representatives attending. One engineer, representing a chemical company, questioned the whole idea. He asked whether it was valid to try to evaluate a computer by applying it to a generalized process. In contrast, an oil company engineer defended the approach hotly, felt the problem was a good one, and represented a good start to spreading understanding of the principles of computing-control.

Some of the questions were quite specific and technical. For example, considerable discussion revolved around the stirred-tank reactor. Was it typical to use such equipment, or would it be more realistic to employ a catalytic reactor? The final answer here was to stick with the original

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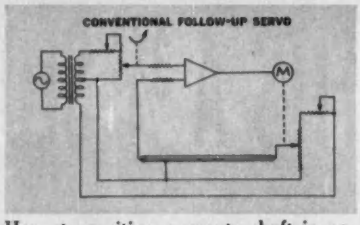
FOR EXAMPLE, a simple follow-up servo:



Here, to position a remote shaft in accordance with the position of the input shaft, resistance potentiometers and summing resistor networks are used. This requires an accurate center-tapped voltage source, so that the two potentiometers will be excited by equal voltages of opposite phase. When the shafts of the two potentiometers correspond, the input to the amplifier will be zero.

THIS TYPE OF CIRCUIT has inherent difficulties:

1) With usual high potentiometer impedances, pickup from stray electrostatic fields may necessitate shielding of the remote signal leads. Shielding and its capacitance increases phase shift.

2) In the summing resistor network, half of the error voltage appears across each resistor, so that only half of the error voltage appears at the amplifier input. This means a loss of gain of one-half, which must be made up by the amplifier.

3) To achieve terminal linearity and resulting servo accuracy, it is often necessary to end-trim conventional potentiometers.

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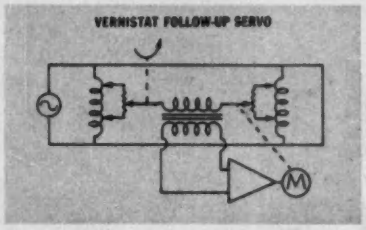

Here, a null transformer provides gain and transmits the error signal directly to the amplifier. Because of this, the amplifier gain requirements are reduced. The error signal is zero when the two Vernistat shafts correspond.

IN THE VERNISTAT CIRCUIT, all signals are transmitted over low impedance leads. This reduces the circuit's susceptibility to pickup and quadrature due to stray capacity. This is particularly important in high gain servo systems.

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38 CIRCLE 38 ON READER SERVICE CARD

WHAT'S NEW

Busy Week in Chicago—AIEE

conditions to avoid complicating the problem unnecessarily.

One difficulty with evaluating the discussion was that not everybody was saying what they meant. One chemical company representative, who had cast doubts on the problem, confided to CtE that his organization really thought it was a good approach. But he had to state doubt for the record because his company was officially bearish on computing-control.

After almost three hours of discussion, the users finally agreed that the AIEE problem represented a good typical approach whose solution would shed considerable light on how to apply computing-control and which would help advance the state of the technology.

• **Makers quandary**—For the maker, the AIEE problem represents a king-sized quandary. A mistake now might jeopardize considerable future business. And as might be expected, the makers debated the problem heatedly. Even more than the users, the makers' discussions reflected important proprietary decisions. For example, one control company urged a postponement of the problem for a year so that it might participate with a computer which will not be available until sometime in 1960.

Most computer manufacturers were concerned with the extremely short deadlines imposed on paper presentation. Because one computer company had already protested to AIEE, the society imposed a strict November 2 deadline on papers for Transactions and a November 27 deadline for conference papers. Computer makers feared this was insufficient time to develop a solution which would probably be widely disseminated to prospective customers.

The dilemma put the makers right in the middle. As one computer engineer put it, "we are damned if we do and we are damned if we don't." His point: if his company didn't prepare a solution, some customers would probably think it couldn't; and if it did, the answer might be topped by a competitor.

The computer suppliers had some technical reservations, too. For example, one representative questioned the value of determining economic payout in the solutions. He felt the real benefit of the study was to show how to solve the problem technically and let the reader attach his own dollar signs to the answer. Based on his intuitive evaluation of the process

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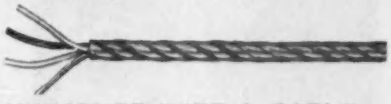

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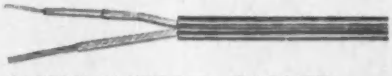

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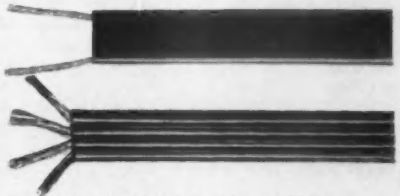

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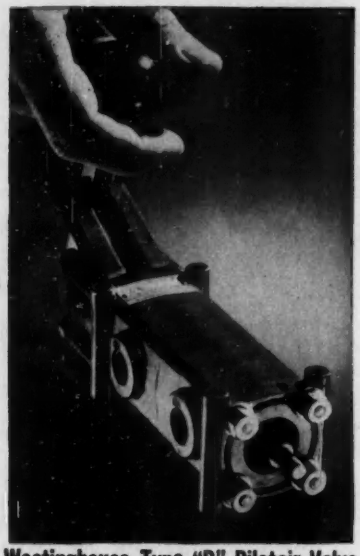
CIRCLE 39 ON READER SERVICE CARD 39

Typical Control Functions solved by AIR CIRCUITRY



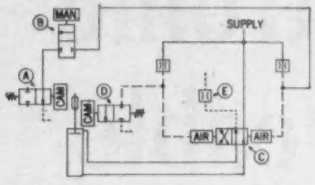
Westinghouse Type "D" Pilotair Valve

Another of Westinghouse Air Brake's many AIR CIRCUITRY components, the "D" PILOTAIR® Valve is a spool-type directional valve that can be operated by a lever, button, cam, solenoid, air pilot, pedal or treadle. Valves available in two, three, and four-way operation, two and three position, open neutral, lap neutral and vented neutral. Port sizes are ¼" and ½" ips. Operators may be on either or both ends. Max. operating pressure: 250 psi.

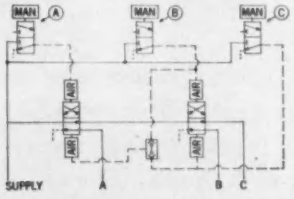
DESIGN FEATURES. A new design of seal and segment construction gives the "D" PILOTAIR® Valve increased capacity and requires a minimum of maintenance. By rotating operators, their mounting brackets and any of their ports in 90° steps, over one-hundred thousand combinations may be obtained. They operate in any position with air, gas, water and most oils. The "D" PILOTAIR® Valve can satisfy any of your directional valve needs. For more information, ask for catalogue A4-75.01.

What is AIR CIRCUITRY?

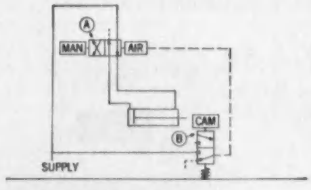
This is the Westinghouse term for application of pneumatic control systems to industrial production operations. Safe, economical, precise Air Circuitry is now being used to solve the most rigorous and complex control problems in industry. Westinghouse Air Brake has pioneered the application and development of air control for more than 80 years. Today our engineers can design an air circuit which will boost production and cut costs.



1. AUTOMATIC CYCLING—Supply air flows to the cylinder to extend the cylinder rod and actuate cam operated valve "A." By operating valve "B" air is bled from the right-hand air pilot of valve "C" to operate this device and retract the cylinder rod. This actuates valve "D" and reverses the process. Cycling time may be changed by regulating the FLOREG® valve "E." The stroke is set by moving the cams on the cylinder rod.



2. STATION TRANSFER—Any of the three stations may capture supply air for the station by operating its respective valve. This may be expanded to any number of stations.



3. AUTOMATIC RESET—To reset the operating valve "A" after completion of an operation. Moving the manual operator admits supply air to the cylinder to extend its rod. At the end of the cylinder rod stroke cam operator valve "B" is actuated to connect supply air to the air pilot operator of valve "A." This returns this valve to its original position. Supply air is then connected to the cylinder to retract the cylinder rod. The circuit is now ready for recycling.

See the Yellow Pages under Cylinders for the Name of Your Local Distributor

WESTINGHOUSE AIR BRAKE COMPANY

INDUSTRIAL PRODUCTS DIVISION, WILMERDING, PENNSYLVANIA

WHAT'S NEW

Busy Week in Chicago—AIEE

flow diagram, another digital computer maker (analog manufacturers were not represented) felt greater economic payout might result in this example by using an analog machine instead of a digital one.

The economic aspects had other ramifications. One computer company's representatives, interested in the Monsanto problem, had to reverse their decision to attend the Skokie meeting. The company's legal department advised against attending when it heard that price was to be incorporated into the answer (the Justice Department in the past has viewed with a jaundiced eye any industry meeting in which price is discussed, has sometimes threatened participants with prosecution on cartel or illegal price-fixing charges).

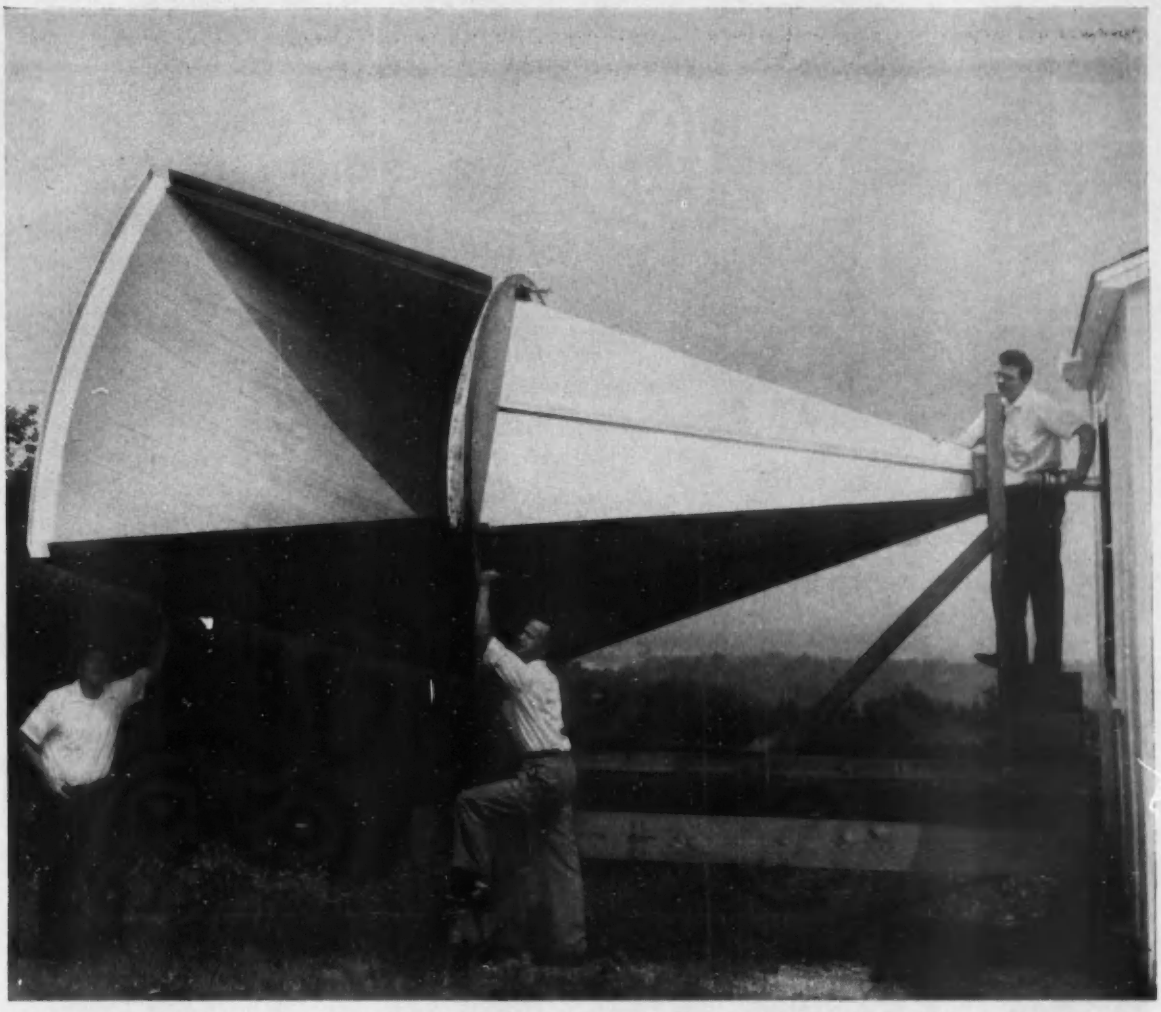
Finally the makers persuaded the group to accept a change in the objective. The papers would state an *approach* to the problem rather than a specific solution. Changing the objective made the problem look tastier to makers for several reasons. Such a paper could be more easily prepared in the short time available, and it would not cost the $10,000 to $30,000 one maker estimated to prepare a complete solution.

Once the users and makers agreed on the value of the problem, the group considered seven proposals to change specific details of the problem. All were voted down so that the problem stands as Dr. Williams' group stated it originally.

Just what will happen now no one is sure. No computer manufacturer representative present would commit himself to preparing a paper. Several told CtE they would try (one representative said it would depend whether his group could come up with an approach or not; they hadn't as yet). Some detailed summaries of papers have already been received by Hollander's subcommittee. And the picture will probably not be cleared until the November 27 deadline has passed.

Despite the heated controversy in one of the most unusual meetings ever held by control engineers, the attendees agreed wholeheartedly that Hollander and Williams should be thanked for their considerable efforts. And a vote of thanks was extended to A. F. Sperry, Panellit's President, for providing the meeting place and dinner for the representatives.

—Harry R. Karp
Lewis H. Young



At Bell Laboratories, Holmdel, N. J., a horn reflector antenna is beamed skyward by scientists Edward Ohm, David Hogg and Robert DeGrasse. The maser amplifier, which employs a ruby cooled in liquid helium, is inside building at right. Over-all "noise" temperature of antenna, amplifier and sky is only 18°K at 5600 megacycles.

ANOTHER STEP TOWARD SPACE COMMUNICATIONS

The above antenna is part of a new ultra-sensitive radio receiving system under development at Bell Telephone Laboratories. It has extraordinary directivity. Beamed skyward, it ignores radio "noise" from the earth, yet picks up extremely weak signals from outer space.

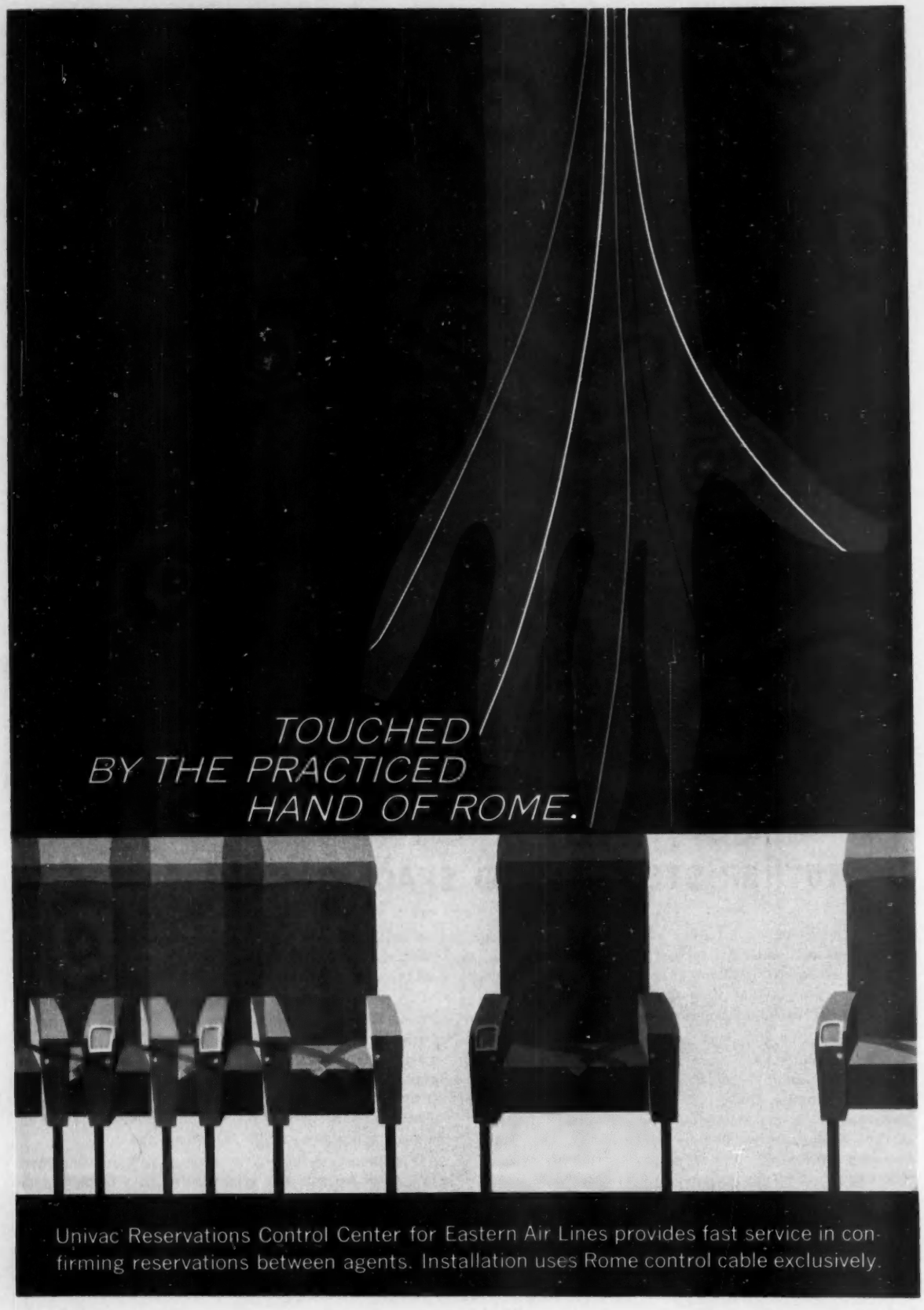
The signals are amplified by the latest Bell Laboratories "maser" amplifier. The maser principle was first demonstrated, using gas, by Prof. C. H. Townes and his collaborators at Columbia University. Bell Laboratories scientists applied it to the solid state guided by a theoretical proposal of Prof. N. Bloembergen of Harvard University. Their latest traveling wave maser amplifier employs a ruby mounted in a waveguide. The ruby is excited to store energy. As signals pass through, they absorb this energy and are thus amplified. The device uniquely combines the characteristics needed for practical space communication: extremely low inherent noise and the ability to amplify a broad frequency band.

At present the receiving system is being used to pick up and measure minute radio noise generated by the atmosphere. It also foreshadows important advances in long distance communications. For example, it could extend the range of space-probe telemetering systems, could help make possible the transatlantic transmission of telephone and TV signals by bouncing them off balloon satellites—and has numerous applications in radio astronomy and radar.

This pioneer development in radio reception is one more example of the role Bell Laboratories plays in the pursuit of better communications technology.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT



Univac Reservations Control Center for Eastern Air Lines provides fast service in confirming reservations between agents. Installation uses Rome control cable exclusively.

How to pick one seat in a million—reliably!

This remarkable Univac equipment locates one seat in a million in seconds to confirm reservations at Eastern Air Lines' new electronic reservation center in New York City.

Failure of any single component would seriously impair the effectiveness of the entire system. That is why all of its complex control-panel connections are made with Rome control cable—insulated and jacketed with Rome Synthinol (PVC) thermoplastic compound for high resistance to oils, acids, alkalies, grease, gasoline and flame.

The Univac links 135 Eastern Air Lines reservations and ticket agents in the New York area, as well as other agents in stations from Boston to Washington. It can store data on one million airplane seats up to one year in advance.

Though constructed with 75 conductors, this specially designed Rome control cable is slim and trim for quick and easy connections even in "tight" spots. Its rugged construction makes it ideal where maximum reliability is necessary.

Rome can help you solve control-panel problems on your job, too. If you need a special cable, as Eastern Air Lines did, Rome's engineers will design and build whatever your equipment requires. If standard cable is adequate for the job, Rome has a wide and complete line for you to choose from. Get in touch the next time you need help: Rome Cable, Dept. 1011, Rome, New York.

ROME CABLE
DIVISION OF **ALCOA**

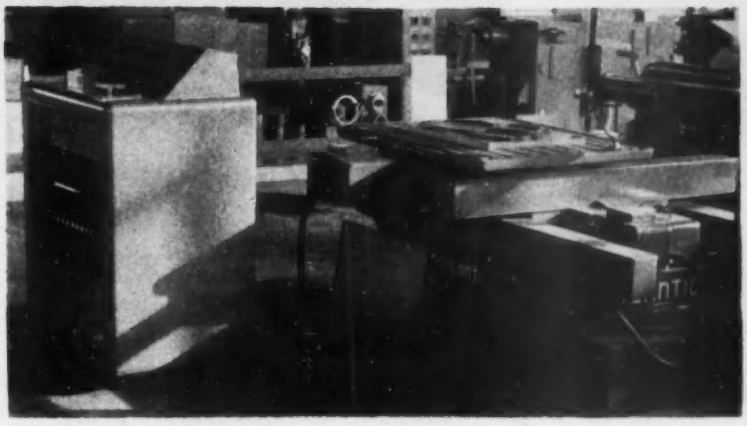
CIRCLE 43 ON READER SERVICE CARD

Disappointment at European Machine Tool Show

Where were the numerically-controlled tools? Where was static switching? Visitors at the Paris Show found few new control systems. Of 4,000 machines, only one used static control; only 12 numerical control systems were on display. Here are some highlights. **Story on page 44.**

Newcomer for jig miller

Plessey Datatrol is available as optional equipment on the Herbert DeVlieg jig miller. Farrand Inductosyn scales replace the normal DeVlieg positioning bars. Course positioning is performed by two sets of resolvers. Final positioning is accomplished by a transistorized unit which generates an error signal to operate the normal DeVlieg positioning cycle. A reverse direction clutch drives the table back towards the reference point, cancelling out the first overshoot. In-line indicators show the coordinate number in operation. Datatrol costs $15,000, almost 60 percent of machine cost.



Low Cost point-to-point

Ferranti reduced cost of its point-to-point positioning system by using five channel punched tape as permanent memory. Information passes to a transistor counter for comparison with table position information generated from 1,000-line per inch diffraction gratings.

Rotary tool magazines

Show standout was this universal jig-borer, built by Ateliers GSP. Mounted on each side of the main column are rotary tool magazines which are advanced by electrical indexing signals. Mechanical arms extract the working tool from the chuck, pick up and insert the next tool from the magazine. Punched film programs table and spindle movements.

interchangeable with all standard JIC cylinders

With the introduction of the ALL NEW T-J Squair Head, Tomkins-Johnson now offers industry the most complete design range of air and hydraulic cylinders. Presently available in bore diameters from 1-½ to 8 inches, the T-J Squair Head is an interchangeable cylinder which produces maximum force and efficiency, with minimum pressures . . . and is also adaptable to the use of low pressure oil as the working medium. Write today to The Tomkins-Johnson Co., Jackson, Michigan, for Bulletin #SQ 10-58 and complete details.

CHECK THESE 10 POINTS OF T-J SUPERIORITY

1. One Piece Piston
2. Hard Chrome Cylinder Bore and Piston Rods
3. High Tensile Steel Tie-Rods
4. Cushion Adjusting Screw, Externally Adjustable
5. New Super-Cushion for air, or Self-Aligning Master Seal for oil (T-J Patents)
6. Solid Steel Heads and Mounting Plates Standard all Models
7. Port Design Allows Minimum Pressure Drop on Inlet or Outlet
8. Chevron Type, Self-Adjusting Rod Packing
9. Piloted Packing Gland—Absolute Alignment
10. Piston Rod, Extra Strong—Polished and Chrome Plated for Efficiency and Protection

T-J TOMKINS-JOHNSON
RIVITORS . . . AIR AND HYDRAULIC CYLINDERS . . . CUTTERS . . . CLINCHORS

44 CIRCLE 44 ON READER SERVICE CARD

WHAT'S NEW

Machine Tool Show Disappointment

(*Pictures on page 43*)

PARIS—

European machine tool control trails far behind U. S. developments. That's the conclusion a visitor had to reach after touring the 1,000 exhibits at the Sixth European Machine Tool Exhibition in Paris's new 370,000-sq ft exhibition hall, the National Center of Industry and Engineering. Only 12 numerical control systems—10 point-to-point and two contouring systems—were on display. Only a single machine of the 4,000 in the show had static controls.

• **Why the lack of new controls?**—Experts blamed three reasons which seem to rule European thinking: 1) no large-scale government-financed aircraft programs, 2) greater availability in Europe of skilled labor at reasonable wage rates, and 3) predominance of small firms with limited capital.

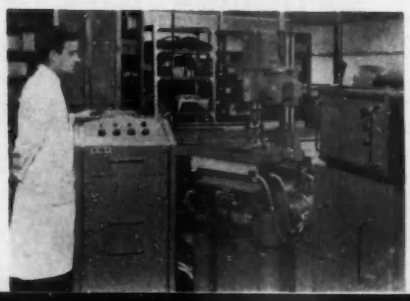
Whatever the reason, European control makers have been unable to cash in on new machine tool control systems. Ferranti, for example, which invested $1.5 million over the last eight years, sees little chance of recouping its investment. In France, Germany, and Switzerland, machine tool builders have eschewed electronic controls. Instead, they are relying on mechanical and electromechanical devices, effective devices such as plugboard programming and solenoid-operated slip gages for sequence and position control. The advantage of such an approach: control system cost becomes a small percentage of the total cost—under 20 percent.

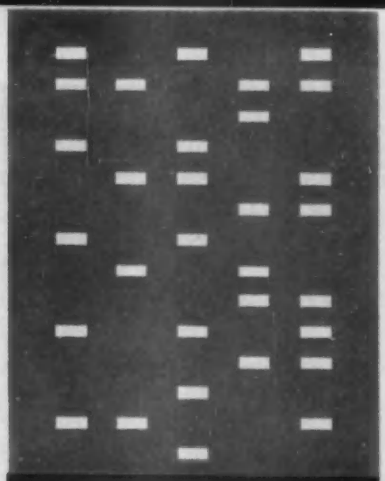
Because of the economics, at least two companies (EMI and Ferranti) are rushing inexpensive ($4,000 to $6,000) positioning systems to market.

—Derek Barlow

EMI's Entry

Low cost competition for Ferranti is this point-to-point system built by EMI Electronics. Input information from either 5-channel punched tape or dial settings is stored on a relay matrix, thus generating X and Y coordinate analog voltages. The system positions X and Y coordinates sequentially. Hydraulic cylinders move the table, which is mounted on recirculating ball slides. Cost of the system: $6,000.

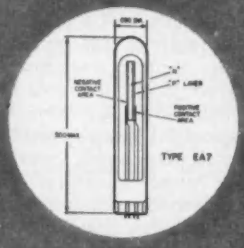




NEW DEVICE TO SOLVE ULTRA-CRITICAL CONTROL-BY-LIGHT APPLICATIONS

FOR MAXIMUM LIGHT SENSITIVITY IN A MINIMUM SIZE

Hoffman Photo-Voltaic Detector Cell "Capsules" are the Answer



Hoffman's newly developed line of especially designed "silicon" photo-voltaic units provide maximum light sensitivity in a minimum size. Provided in a large variety of shapes, segmentations, configurations and encapsulations, the "Detector Cell Capsules" provide greatest possible design flexibility. Wide number of ideal applications for these units include: computers (punched card and tape readouts), detector instrumentation, programming controls, infrared sensors, counting devices, remote switching systems, and automatic "triggering" equipment.

This sub-miniature, hermetically sealed device has a storage temperature range of from −65°C to +175°C; response time of −20 microseconds; illumination level required 1250 ft. candles (tungsten light @ 2800°K); peak spectral response of 8500 angstroms.

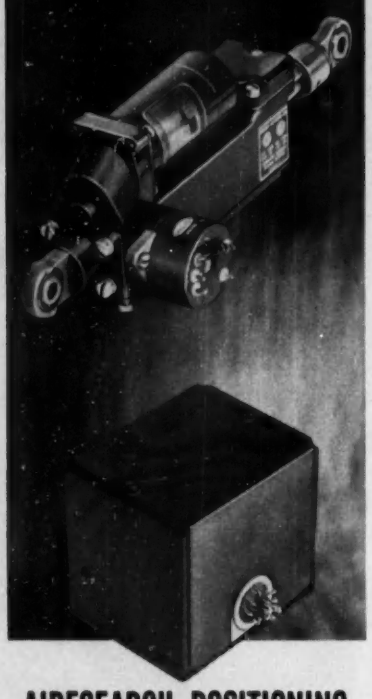
For design consultation and information, contact your nearest Hoffman semiconductor representative.

One of the series of new "dedication" products being manufactured in Hoffman's new El Monte, California plant.

Hoffman Electronics
CORPORATION
SEMICONDUCTOR DIVISION
Plants in El Monte, California and Evanston, Ill.

CIRCLE 45 ON READER SERVICE CARD

Electromechanical Components and Systems Capability



AIRESEARCH POSITIONING CONTROL SYSTEMS

One of the many types of high speed positioning control systems produced by AiResearch, the system above amplifies electric signals from an inertial guidance source and adjusts the control surfaces of the missile or drone to maintain a predetermined course.

AiResearch diversification and experience provide full capability in the development and production of electromechanical equipment and avionic controls for aircraft, ground handling, ordnance and missile systems.

A.C. and D.C. Motors, Generators and Controls • Inverters • Alternators • Linear and Rotary Actuators • Power Servos • Hoists • Electrical Pyrotechnics • Antenna Positioners • Positioning Controls • Temperature Controls • Sensors • Williamsgrip Connectors • Static Converters.

Your inquiries are invited.

THE GARRETT CORPORATION

AiResearch Manufacturing Division

Los Angeles 45, California

AROUND THE BUSINESS LOOP

Organized planning with a psychological base will be applied to control problems as this company, better known for making data handling equipment, expands into new fields.

BERNARD S. BENSON: Engineering with a flair for psychology opens up new markets in control.

Benson-Lehner Aims Organized Thinking at Control

LOS ANGELES—"In a year, there will be few areas of control in which we will not have a strong interest," says George Hoover, director of technical planning at Benson-Lehner Corp., maker of data handling equipment. The company which Bernard S. Benson and George Lehner founded nine years ago has set its sights on new horizons. Its first sale of stock to the public this summer has brought in cash to finance a round of acquisitions and to redesign some of the company's products.

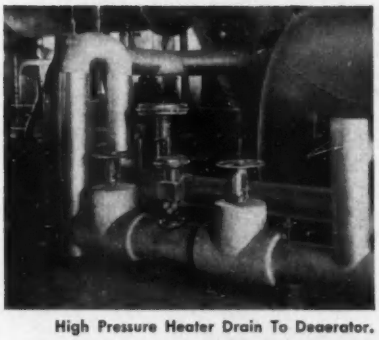
Since it was founded, the Benson-Lehner Corp. has been a bit of an enigma to many control engineers. Benson, its highly vocal head (he once wrote an article for *Fortune* magazine blasting brainstorming), refused to follow along staid conservative paths. He has plugged organized thinking as a method of solving problems; he has insisted on emphasizing man-machine relations in designing his hardware. And, the company has a very strong psychologically-oriented base, an oddity for an engineering company. Co-founder Lehner is still a full professor of psychology at University of California at Los Angeles.

But Benson's organized planning and man-machine emphasis have paid off. The company has showed a small, but consistent, profit almost every year (it's only money-losing year was 1954 when the company dropped $68,000 on sales of $521,215). Until now, this concentration has manifested itself in data handling equipment. The B-L Oscar, a semiautomatic data analyzer, and Boscar, a modified version for photo-recorded data, are familiar devices in military and civilian test facilities. In addition, B-L has marketed such devices as a magnetic tape converter; it has established two subsidiary companies overseas in France (in 1954) and in England (in 1957).

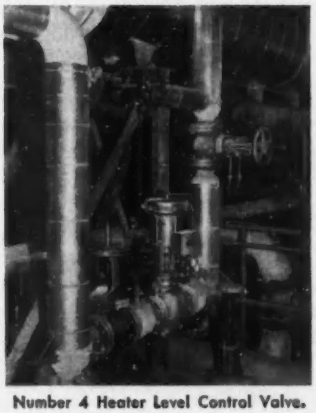
• **Open for growth**—Now B-L is readying its biggest growth to date. From the R&D laboratory a flock of new products are ready to be introduced. The one the company is most enthusiastic about is Digitape, a metallized Mylar, inch-wide tape, across which 32 bits can be recorded by electrically removing metal film. Longitudinal spacing is approximately 50 lines per inch so that Digitape will supply both the high speed, high density advantages of magnetic tape and the permanence and storability of paper tape. Benson says it will be adaptable to virtually all digital systems by the addition of Benson-

General Plant View.

Clinch River Plant, Units 1 & 2



High Pressure Heater Drain To Deaerator.



Number 4 Heater Level Control Valve.

Highlighting the vast power expansion program of the American Electric Power System, two additional 225,000 KW steam-electric generating stations were recently put on the line by the Appalachian Power Company.

In these fully automatic reheat stations, BS&B Super 70 Control Valves, together with BS&B Liquid Level, Pressure and Temperature Controllers, are employed in heater drain and other auxiliary control systems.

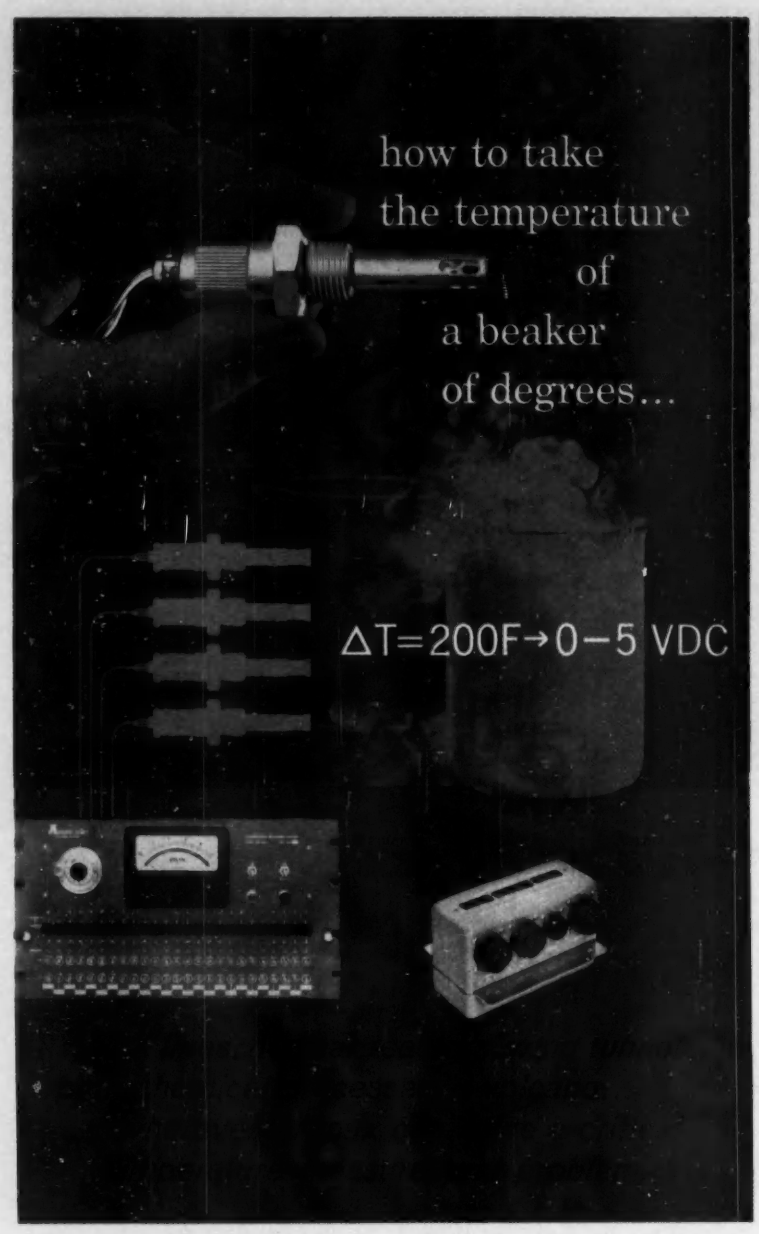
Engineering service, including preliminary engineering studies, multi-load analysis and start-up assistance were provided with BS&B Controls in the Clinch River Plant to assure unit responsibility as well as efficient and dependable system performance.

In the two world's-largest forthcoming 450,000 KW super-critical once-through stations, BS&B Controls will again render proud service to the Power Industry through the American Electric Power System.

BLACK, SIVALLS & BRYSON, INC.
Controls Division, Dept. 4-ES11.
7500 East 12th Street • Kansas City 26, Missouri

SUPER BS&B 70

CIRCLE 47 ON READER SERVICE CARD



Solutions to temperature-measurement problems are not so elusive once an Arnoux high-level-output temperature-measurement system (TME) is installed. The multichannel, solid-state TME, a complete package, is versatile in application, flexible in use. TME features range selection, expandable temperature span, recalibration in seconds... direct high-level-voltage readout... dc amplifiers are completely unnecessary; result: low, low cost per channel... total range from −320F to +1000F... available in airborne or ground versions.

ARNOUX CORPORATION

11924 W. Washington Blvd. • Los Angeles 66, Calif.

ARNOUX

PHONETICALLY, SAY ARE'NEW

TEMPERATURE-MEASUREMENT SYSTEMS

48 CIRCLE 48 ON READER SERVICE CARD

WHAT'S NEW

. . . numerical control, medical gear through evolution . . .

Lehner input and output devices.

Digitape seems sure to aim the B-L organization into new fields. For example, the numerical control of machine tools may turn out to be a big user of Digitape. Under Benson's concept of organized thinking, the company can be expected to take a good look at numerical control systems and probably to come up with some brand new products.

In the field of photo-instrumentation, one the company has always been interested in, B-L has developed a wide-angle "strike" camera to record the flight and impact of air-launched missiles from the launching plane. Another new device, The Benson-Lehner Stereomat, interprets photographs, automatically measures distances on stereo photos.

• **Medical Instrumentation**—Still another new area for Benson-Lehner is the field of medical instrumentation. Growth here will be headed by George Hoover, who was the company's best known addition when he joined B-L in 1959. Hoover had a spectacular scientific career in the U.S. Navy's Office of Naval Research. He had been the motivating force behind the Army-Navy Instrument Program to update the cockpit of operational aircraft, and he had called the meeting to plan Project Orbiter, the U.S.' first satellite proposal. Hoover too had always exercised an emphasis on the man-machine relationship. Now at Benson-Lehner, he is following some pet paths that he expects will lead to a complete line of medical instrumentation.

Hoover will take Benson-Lehner into some pure study areas, too. For example, the former Navy commander is determined to investigate the psychological effects of weightlessness on man during space and satellite flights. Such an investigation would utilize many aspects of the company's talents: it's soon-to-be born line of medical instruments, its data handling devices, and its organized thinking approach. Because of its psychological overtones, the work fits right into the thinking of the firm's founders.

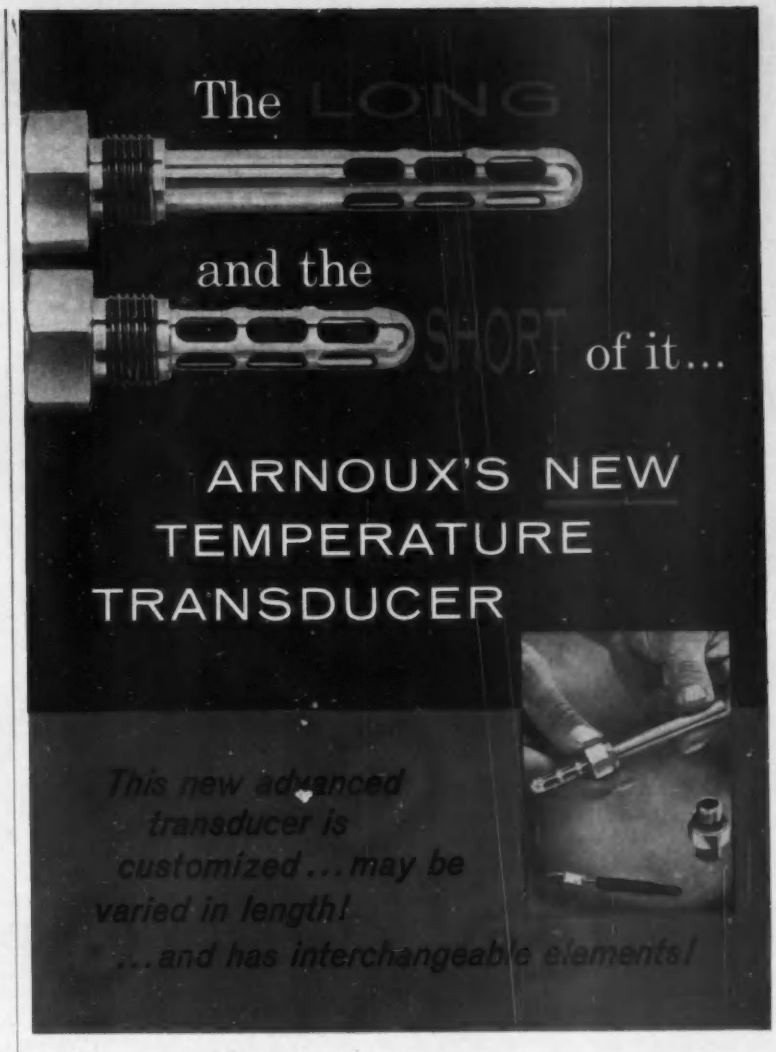
• **Acquisitions on the rise**—With money raised by a public sale of stock, Benson-Lehner is ready to expand by acquisition too. This summer, for example, it acquired a small organization, Data Services, whose main business was taking raw data and converting it to a form more useful for its

customers. B-L is now expanding the facilities of the new subsidiary by adding to its computer facilities. On October 25, B-L finalized an agreement leading to the acquisition of Documentation, Inc., a Washington, D.C., company doing about a $1 million per year as a consultant in data processing and as an operator of data processing facilities. Just how well it will fit into the plans of B-L can be seen by its background in medical data processing. It has been handling computations for the National Institute of Health's Cancer Chemotherapy program.

Under Benson's critical eye, B-L has always shown more than ordinary interest in the appearance of its hardware. A competitor once claimed that Benson sold his instruments by painting them to match the decor of a potential customer's surroundings when equipment was sent out for demonstration. Benson denies it. But the company's data handling equipment has always been attractive. Today, the established products of the company are undergoing another face-lifting, one that has as much to do with function as appearance. The first machine to get modernized was Oscar, whose new look was displayed at the ISA show in September. Not only has Oscar been streamlined, but all components have been incorporated into a single console, eliminating the extra cabinet which used to be required for digitizing and accessory equipment. The other products are also scheduled for a repackaging.

• **Foreign chips** – While Benson plans a broad expansion in the U.S., applying his problem-solving approach to control systems on a broad front, he also has a keen interest in foreign sales. Don Prell, B-L's vice-president in charge of applications engineering (who has a BS degree in psychology from UCLA), predicts a rapid expansion of the company's two foreign subsidiaries to take advantage of the European Common Market. Last year, overseas sales made up 15 percent of B-L's sales, but Prell expects this to rise sharply.

The new look of B-L and its impact on the control field has been carefully planned. Benson and his associates have put their psychological approach to gaging the growth of their company, have developed a series of three-dimensional models to represent planned one-year, five-year, and ten-year growth. The models show startling growth, even compared to how far B-L has come since its start in 1950 on $5,000 of borrowed capital (plus 25 cents in Benson's pocket) to expected 1959 sales of $4 million. –Jack Meyer



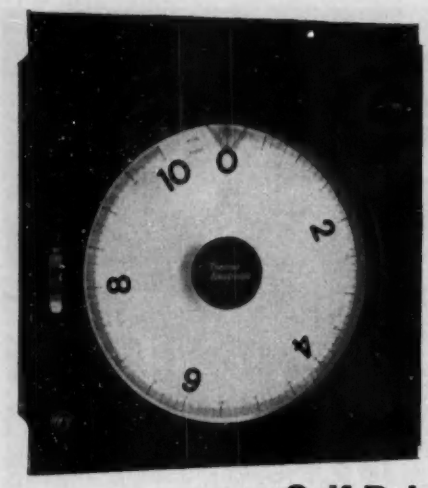
Arnoux's *new* unique temperature transducer, solving several problems, is an advanced concept in resistance thermometry. It's modular... simple to provide in variable tube lengths, from 1⅛ to 2⅝ inches—special lengths on request... all parts are interchangeable, simplifying replacement or reuse; and, replaceable, humidityproof sensing elements... available in either gas- or fluid-immersion types with sensing elements of nickel-iron, platinum, or thermistor (semiconductor oxides).

Other features: With suitable circuitry, outputs of from 0 to 5 volts; ranges of from –320 F to 1000 F; mounting permits variation in tube length —also changing element while fitting is in place; LOX compatible; pressure rating, fluid-immersion, 4500 psi to 1000 F; pressure rating, gas-immersion, 4500 psi at 77 F and 2000 psi at 1200 F; resistance tolerance to 0.5%; and, solder terminals for increased reliability. Bulletin 308.

Arnoux Corporation
11924 W. Washington Blvd. • Los Angeles 66, California

ARNOUX
phonetically, say Are'new
TEMPERATURE TRANSDUCERS

CIRCLE 49 ON READER SERVICE CARD 49



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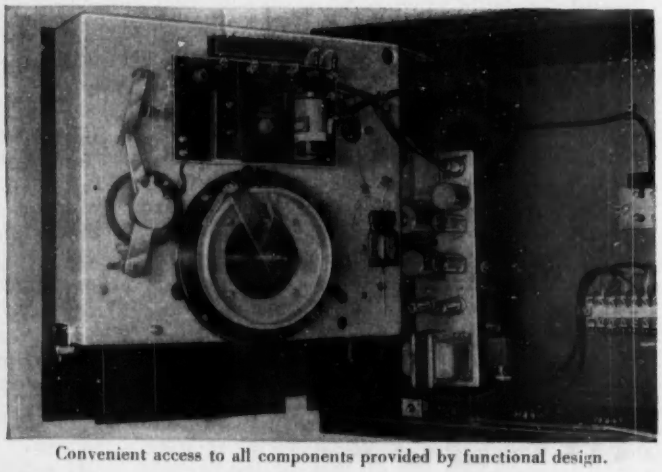

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WHAT'S NEW

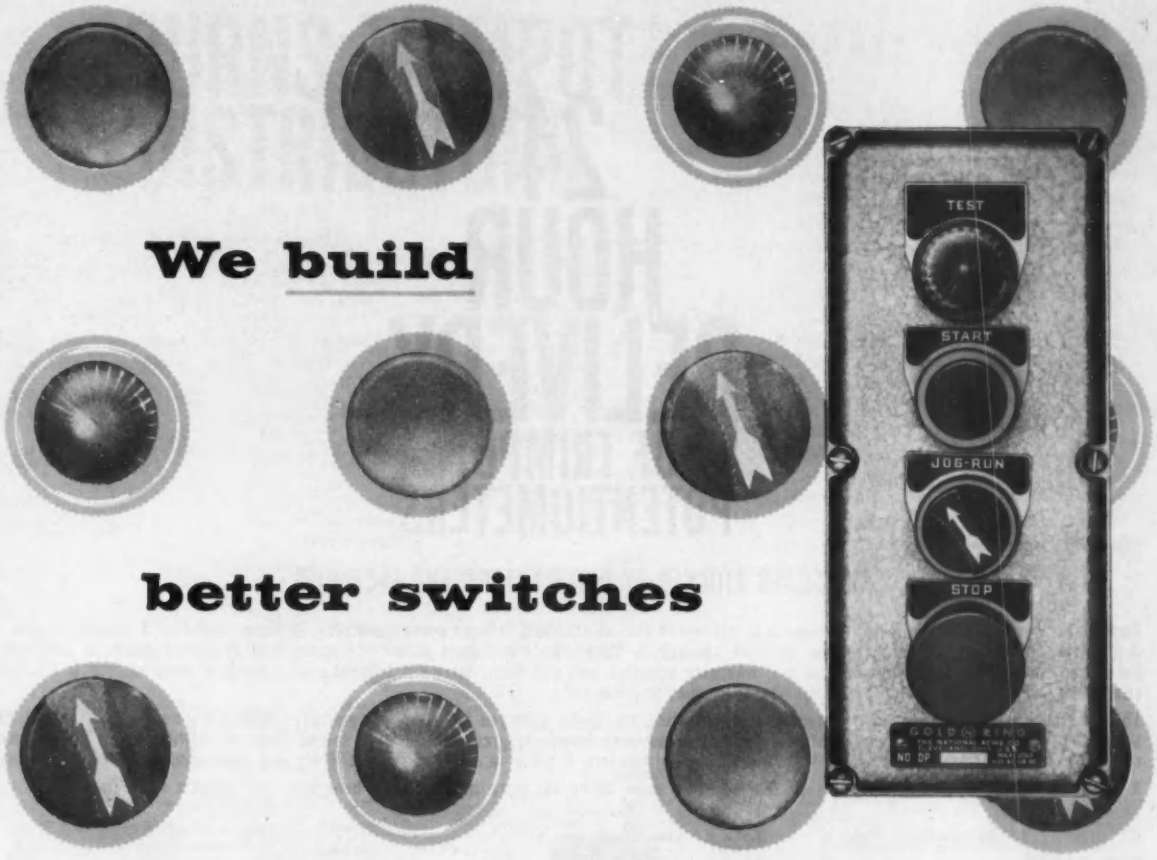
"Soaring Sixties" Forecast At Sales Outlook Session

An air of little-tempered optimism pervaded the recent 1960 Sales Outlook session of the National Industrial Conference Board's annual marketing conference. Experts on the markets for eight key industries predicted sales volume for their portion of the economy for next year. The consensus: another boom year, sales up all around. Most estimates were tinged with some uncertainty about the effects of the steel strike, but the major effect of an extraordinary extension of the dispute should be only increased carry-overs of business to next year's books. So this year might be down a bit from previous estimates, but 1960 would be bigger than ever. The rundowns and experts reporting follow:

• **Steel**—Tom Campbell, Editor-in-chief, *The Iron Age*: Steel ingot output in 1960 will approach 130 million tons (1959 consumption should run about 120 million ingot tons). Supporting this estimate: a big order carry-over from 1959 as the result of the extended strike, a 7.2 million car year (some see 8 million) for Detroit auto makers, a smaller drop in housing than some observers forecast, an increase in steel use in all construction (2 million more ingot tons), warehouses in need of stocking up after this year's inventory depletion, higher new plant and equipment buying ($35 billion or more), and no cold war change with continuing $40-billion defense spending.

• **Nonferrous Metals**—Charles R. Ince, vice-president and sales manager, St. Joseph Lead Co.: Qualified by uncertainty over the steel dispute and strikes in the nonferrous industry, copper should have a good year and rise from an estimated 1.50 million tons delivered in 1959 to between 1.60 and 1.65 million tons in 1960 (up 10 to 15 percent); lead consumption is expected to rise 2 percent from 1959's 1.08 million tons; and zinc consumption presents the brightest picture, to be up 8 percent to about 1.08 million tons.

• **Machinery and Equipment**—Stuart H. Smith, vice-president in charge of sales, SKF Industries, Inc.: 1960 will be a good business year; *It is the first of the soaring sixties.* Sales in machinery and equipment should be 12½ to 15 percent above 1959. In particular: passenger cars, up 4 percent over this year; trucks, 1 percent; air-borne equipment (aircraft, missiles, space ve-



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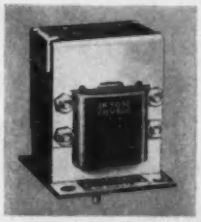

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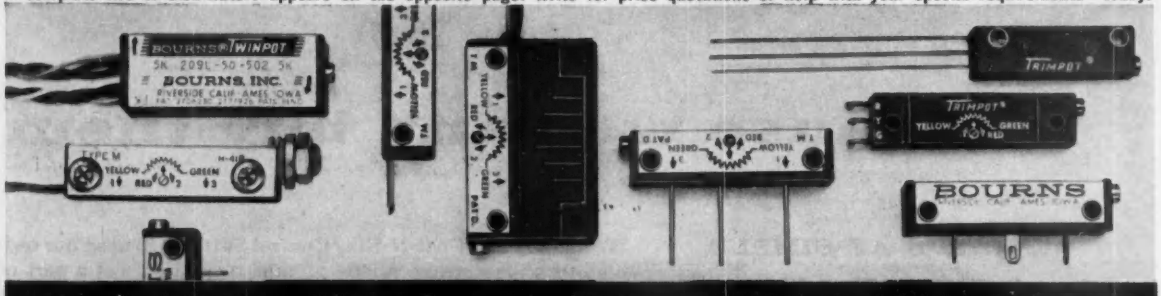

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218 N. 1st Avenue
Phone: MA 3-2545

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Phone: EXmont 1-6201

INGLEWOOD
Liberty Aircraft, Inc.
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Phone: ORegon 8-7163

Newark Electric Co.
4747 W. Century Blvd.
Phone: ORegon 8-0441
TWX: INGL 2365

LOS ANGELES
Kierulff Electronics, Inc.
820-30 W. Olympic Blvd.
Phone: Richmond 7-0271
ZEnith 0271

OAKLAND
Elmar Electronics
140 Eleventh Street
Phone: HIgate 4-7011
TWX: OA-73

SAN DIEGO
Atlas Electronic, Inc.
4618 Santa Fe Street
Phone: BRoadway 4-3131

Western Radio and TV Supply Co.
1415 India Street
Phone: BEImont 9-0361

SAN FRANCISCO
Pacific Wholesale Co.
1850 Mission Street
Phone: KLondike 2-0700

COLORADO

DENVER
Denver Electronic Supply Co.
1254 Arapahoe Street
Phone: AMherst 6-1671
TWX: DN 941

CONNECTICUT

NEW HAVEN
Radio Shack Corp.
230-234 Crown St.
TWX: NH 466
Phone: SP 7-6871

D. C.

WASHINGTON
Capitol Radio Wholesalers, Inc.
2120-22 Fourteenth Street, N.W.
Phone: HObart 2-0800

FLORIDA

MIAMI
Electronic Supply
61 N.E. Ninth Street
Phone: FRanklin 7-2511
TWX: MM 186

MELBOURNE
Electronic Supply
Post Office Box 1655
909 Morningside Drive
Phone: PArkway 3-1441
TWX: 7138

ORLANDO
Goddard — Orlando
631 W. Central Avenue
Phone: GA 5-5531

WEST PALM BEACH
Goddard Distributors, Inc.
Post Office Box 829
1309 North Dixie
Phone: TEmple 3-5701
TWX: WP-38

GEORGIA

ATLANTA
Electro Air Corporation
645 Antone Street, N.W.
Phone: TRinity 3-1651

ILLINOIS

CHICAGO
Allied Radio Corp.
100 North Western Ave.
Phone: HAymarket 1-6800

Newark Electric Co.
223 W. Madison Street
Phone: STate 2-2944
TWX: CG 1401

INDIANA

FORT WAYNE
Ft. Wayne Electronics Supply, Inc.
3606 Maumee Ave.
Phone: EAstbrook 3431

INDIANAPOLIS
Graham Electronics Supply, Inc.
122 South Senate
Phone: MElrose 4-8488

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Post Office Box 1499
Phone: ATlantic 8-4779

IOWA

CEDAR RAPIDS
Deeco, Inc.
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Phone: EMpire 4-2491

MARYLAND

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2025 Worcester Street
Phone: SAratoga 7-5100

Kann-Ellert Electronics, Inc.
Howard & Redwood Streets
Phone: SAratoga 7-4242
TWX: BA 587

SILVER SPRING
Kann-Ellert Electronics, Inc.
11222 Triangle Lane
Phone: LOckwood 5-5200

MASSACHUSETTS

BOSTON
Radio Shack Corporation
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Phone: REgent 4-1000
TWX: BKN 262

CAMBRIDGE
Electrical Supply Corp.
205 Alewife Brook Parkway
Phone: UNiversity 4-6300
TWX: CAMB MASS 429

MICHIGAN

DETROIT
Ferguson Electronic Supply Co.
2306 Puritan Street
Phone: UNiversity 1-6700
TWX: DE 803

MINNESOTA

MINNEAPOLIS
Lew Bonn Co.
1211 LaSalle
Phone: FEderal 9-6351

MISSOURI

ST. LOUIS
Interstate Supply Co.
4445 Gustine Ave.
Phone: FLanders 1-7585

NEW JERSEY

CAMDEN
General Radio Supply Co., Inc.
600 Penn Street
Phone: WOodlawn 4-8383 (N.J.)
WAlnut 2-7037 (Phila.)

CLIFTON
Eastern Radio Corp.
312 Clifton Ave.
Phone: GRegory 1-5600

MOUNTAINSIDE
Federated Purchaser, Inc.
1021 U.S. Route 22
Phone: ADams 2-8200
TWX: WSFD NJ 319

NEW MEXICO

ALAMOGORDO
Radio Specialties Co.
209 Penn Ave.
Phone: HEmlock 7-0370
TWX: 5671U

ALBUQUERQUE
Electronic Parts Co.
222 Truman St., N.E.
Phone: ALpine 6-0946

Radio Specialties Co., Inc.
6323 Acoma Street, S. E.
Phone: AMherst 8-3901
TWX: AK 561

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BINGHAMTON
Federal Electronics, Inc.
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BUFFALO
Radio Equipment Corp.
312 Elm Street
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JAMAICA
Peerless Radio Dist., Inc.
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Phone: REpublic 9-6080

MINEOLA, L. I.
Arrow Electronics, Inc.
525 Jericho Turnpike
Phone: Pioneer 6-8686
TWX: G CY NY 460

Schweber Electronics
Post Office Box 669
60 Herricks Road
Phone: Pioneer 6-6520
TWX: GLY NY 580

NEW YORK
Harrison Radio Corp.
225 Greenwich Street
Phone: BArclay 7-7777
TWX: NY 1-177

Harvey Radio Company, Inc.
103 West 43rd Street
Phone: JUdson 2-1500

Hudson Radio and TV Corp.
37 West 65th Street
Phone: TRafalgar 3-2900

Milo Electronics Corporation
530 Canal Street
Phone: BEekman 3-2980
TWX: NY 1-1839

Sun Radio and Electronics
650 Sixth Ave.
Phone: ORegon 5-8600
TWX: NY 1-4022

Terminal Radio Corp.
85 Cortlandt Street
Phone: WOrth 4-3311

ROCHESTER
Rochester Radio Supply Co., Inc.
600 East Main St.
Phone: LOcust 2-9900

SYRACUSE
Syracuse Radio Supply Co.
620 South Salina Street
Phone: 74-2927

NORTH CAROLINA

WINSTON-SALEM
Dalton-Hege Radio Supply Co.
912 West 4th St.
Phone: 5-8711
TWX: W-Sal 373

OHIO

AKRON
Akron Electronic Supply, Inc.
107-117 South Arlington St.
Phone: POrtage 2-8818

CINCINNATI
Herrlinger Distributing Co.
115 Corwine Street
Phone: GA 1-5282 TWX: CI 125

COLUMBUS
Thompson Radio Supplies, Inc.
182 East Long St.
Phone: CApital 1-7434

DAYTON
The Stotts-Friedman Company
108-112 North Jefferson Street
Phone: BAldwin 4-1111

OKLAHOMA

TULSA
Indel Supply, Inc.
Post Office Box 3443
538 South Lewis Avenue
Phone: WE 9-7585

PENNSYLVANIA

PHILADELPHIA
Albert Steinberg & Company
2520 North Broad Street
Phone: BAldwin 3-9400

Almo Radio Co.
913 Arch Street
Phone: WAlnut 2-5918

PITTSBURGH
Cameradio Co.
1121 Penn St.
Phone: EXpress 1-4000
TWX: PG 438
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Phone: UNion 1-2800

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TWX: NNG

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UTAH

SALT LAKE CITY
Standard Supply Co.
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Phone: ELgin 5-2971

WASHINGTON

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Seattle Radio Supply, Inc.
2117 Second Avenue
Phone: MA-2345

TACOMA
C & G Radio Supply Co.
2502 Jefferson Street
Phone: BRoadway 2-3181

WISCONSIN

MILWAUKEE
Taylor Electric Co.
4080 N. Port Washington Rd.
Phone: WOodruff 4-4321
TWX: MI 118

hicles, and related control systems), 20 percent; construction, mining, and oil field equipment, 15 percent; electrical machinery, 15 percent; farm machinery, 5 percent; railroad freight cars, 30 percent; internal combustion engines, 15 percent; office machinery, 7½ percent; conventional military ordnance, about the same. Smith's figures cover only those industries using ball and roller bearings (SKF's products) but include the greater part of the machinery and equipment field.

• **Automobiles**—Herbert A. Boas, Jr., vice-president and director of marketing, The Budd Co.: Domestic sales of passenger cars should be in the neighborhood of 6 to 6½ million (less optimistic than Campbell).

• **Construction**—Walter E. Hoadley Jr., treasurer, Armstrong Cork Co.: Volume of new housing should drop 10 to 15 percent; total construction will level off.

• **Chemicals**—Allan B. Clow, vice-president for marketing, American Cyanamid Co.: A peak year is expected with overall production up 10 percent over 1959.

• **Petroleum**—E. H. Lyon, vice-president, sales, Phillips Petroleum Co.: Overall domestic demand will increase 3 percent over 1959 to 10 million bpd.

• **Textiles**—John J. Moran, vice-president in charge of sales, Pepperell Manufacturing Co., Inc.: The industry is optimistic over 1960 prospects, but it is anxious over problems with cheap foreign imports.

What does all this mean to instrument and control makers? It indicates increasing and unprecedented demand for instruments and controls as manufacturers need larger shipments of components for their equipment and, along with the process industries, spend near-record amounts on new producing equipment and facilities to keep production up with sales.

IRC, CTS Strike Novel Sales Bargain

International Resistance Co. and Chicago Telephone Supply Corp. have reached a unique marketing agreement; IRC will become sales reps for CTS variable resistor products in five major sales areas. The deal gives CTS broader sales coverage and means the addition of the CTS line to IRC's line of components.

The arrangement follows up one made in April whereby IRC Distributor Div. became a wholesale customer of CTS for resale to jobbers.

Makers, Independents Join Computer Center Scramble

A new look in computer marketing policies is rapidly taking shape. Large-scale computer makers and independent firms are rushing plans to set up data processing service centers in important business areas. Latest to announce such a program is CEIR (Corporation for Economic and Industrial Research) which plans to establish a chain of computer service centers in five big city areas.

CEIR's entry followed up the recent decision by IBM to sell time on its solid-state 7070's by the hour in 25 service centers (see CtE, Sept. '59, p. 50) and RCA's announcement of a Wall Street service facility using its transistorized 501. Other computer makers, when queried by CtE, were mum about some details of their plans, but most admitted that they will soon have computer centers in operation to meet the competition.

CEIR claims that their centers will offer the most advanced equipment yet announced for such use. The first three, to be set up in the New York City, Houston, and Washington, D. C., areas will house IBM 7090 computers already ordered by CEIR. A comparable machine will be chosen from those available in 1960 for the center planned for the Chicago area. The most powerful computer available in mid-1960 will be operated in a center in the Los Angeles area.

CEIR, a Washington consulting firm, claims that its approach—the same as that of the computer makers (who would, however, rather sell or lease the machines)—is the only answer to business' computing problem. They point out that the high speed machines will be essential because of their low cost per solution, but that even large companies will not be able to keep them busy enough to recover their cost. The centers will provide programming and operating services.

RCA is expected to set up a dozen 501 centers. The first is already operating in its Cherry Hill, N. J., plant and showroom, and the next center will begin operation at the beginning of 1960, serving several Wall Street stock brokerage firms. In the financial district installation, RCA personnel will operate the machines using programs worked out with the brokers' help. At first, tape reels will be hand-carried between the center and input and output devices in the brokerage houses. Eventually, though, direct lines will allow "untouched-by-human-hands" operation. In either case no house will have access to another's transactions.

Minneapolis-Honeywell will join the race with several centers employing its Datamatic Div.'s Honeywell 800. First areas to be served will be New York City, Boston, Chicago, Los Angeles, and Washington, D. C. The Boston center is expected to be in operation by April 1960, with other centers following through the next year. Honeywell sees these centers as an important part of its operations and expects them to serve a varied customer market with different data processing needs. Some users will do their own programming and operation while others will have the work done for them by Honeywell personnel. Some work will be done for companies that cannot afford their own computer; other users will be firms who do have one but need peak load facilities.

National Cash Register expects to open its first center employing its 304 machine in New York City in June 1960. Another will follow soon after at NCR's Dayton, Ohio, home plant; sites for other expected centers have not yet been chosen. Biggest users of National Cash centers would be owners of the company's tape producing accounting machines. Customers would supply the tapes for computation and printing. Operation would be by the customer or NCR.

Transac centers from Philco are still a question mark. Philco admits only that it is contemplating such an operation, but in view of the activity by the competition, it's doubtful if the company will hold back.

The service center move is a big one for the computer field. Each RCA 501 installation is worth about $1.2 million, each Honeywell 800 or NCR 304 about $1 million. IBM will be taking a huge step with 25 of its million dollar-plus 7070's. An important by-product of a center set up by a computer maker is a super showroom. Potential customers will have a chance to see the machines in operation, to try them out for short periods, and, when they decide to lease or buy, to train their personnel, and even run solutions while awaiting delivery.

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NEW YORK: Hudson Radio & Television Corp., 37 W. 65th St., N. Y. C.; Sun Radio & Electronics Co., Inc., 650 Sixth Ave., N. Y. C.

OHIO: Buckeye Electronics Distributors, 236-246 E. Long St., Columbus; The Mvtronic Co., 2145 Florence Ave., Cincinnati; Pioneer Electronic Supply Co., 2115 Prospect Ave., Cleveland.

OKLAHOMA: Oil Capitol Electronics, 708 S. Sheridan, P. O. Box 5423, Tulsa.

PENNSYLVANIA: D & H Distributing Co., 2535 N. 7th St., Harrisburg; Herbach & Rademan, Inc., 1204 Arch St., Philadelphia.

WASHINGTON: Seattle Radio Supply Co., 2115 2nd Ave., Seattle.

WISCONSIN: Radio Parts Co., Inc., 1314 N. 7th St., Milwaukee.

CIRCLE 54 ON READER SERVICE CARD

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Automatic MINIATURIZED silicon power rectifiers

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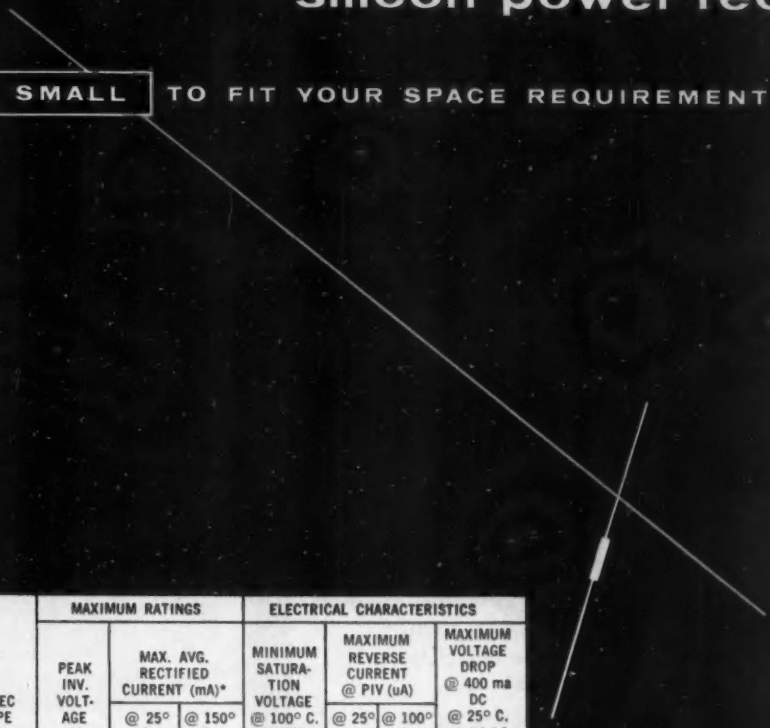

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		@ 25° C.	@ 150° C.		@ 25° C.	@ 100° C.	
1N645	225	400	150	275	0.2	15	1.0
1N646	300	400	150	360	0.2	15	1.0
1N647	400	400	150	480	0.2	20	1.0
1N648	500	400	150	600	0.2	20	1.0
1N649	600	400	150	720	0.2	25	1.0

*Resistive or inductive load

We've shrunk the size, but not the quality. All the outstanding characteristics and reliability you expect of products from General Instrument Corporation are present in these miniaturized units. Data sheets on these and other Automatic silicon rectifiers are available upon request.

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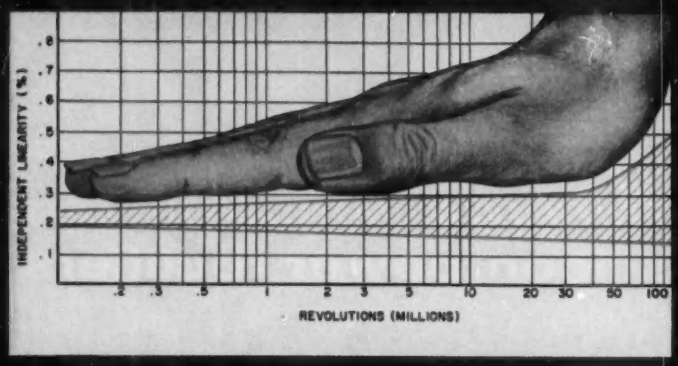

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- **Operation under all applicable Military Specifications.**

Write for Design Data and Catalog for Rotary and Rectilinear Potentiometers

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WHAT'S NEW

Norden Overcomes Resistance; One-Year Plant Hunt Ends

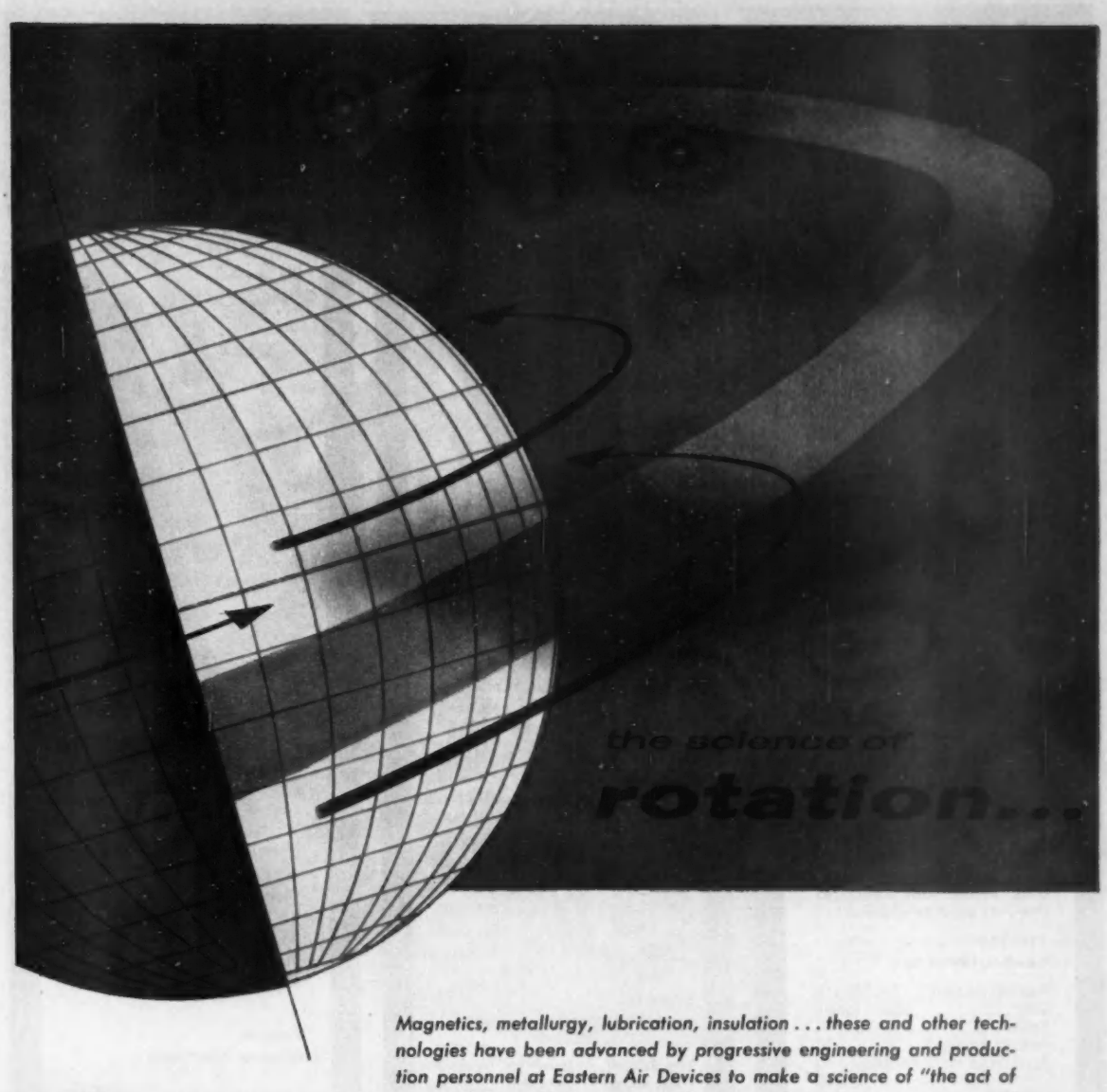
Climaxing an extensive search that began soon after Norden-Ketay became a division of United Aircraft Corp. in July 1958, the Norden Div. has finally found a permanent place to hang its hat. Norwalk, Conn., will be the site of a "multimillion dollar" office, engineering, research, and manufacturing facility that is expected to be completed about a year from now.

Norden ran into the sort of resistance that should have been outdated by today's "park-like" and "campus-style" industrial facilities, but has been plaguing many companies seeking to expand. Fairfield, Conn., and Westchester, N. Y., county homeowners, intent on preserving the "residential flavor" of their respective communities, blocked the electronics-oriented division's house-hunting. That is, until the Connecticut Development Commission and State Highway Dept. got together with farsighted Norwalk town officials to bring about what is a long-accepted phenomenon in several other Connecticut towns—UAC at or near the top of the tax rolls (Sikorsky in Bridgeport and Stratford; Hamilton Standard in Windsor Locks and Broad Brook; Pratt & Whitney Aircraft, Missiles and Space, Research, and corporate offices in East Hartford; P&WA's AEC nuclear engine lab in Middletown; plus warehouses, foundries, etc. scattered throughout other towns and cities). Robert A. Aspinwall, Norden's general manager, relieved that the quest was over, publicly thanked the two state agencies and the town mayor for their assistance.

The new plant, a 350,000-sq ft building on an 80-acre tract, will bring under one roof the operations carried on in Stamford and Milford, Conn., and White Plains, N. Y. Not affected are the division's units at Commack, Long Island, and Gardena, Calif. Aspinwall hinted, however, that if Norden's business continued to expand, the Milford plant may be continued. The new plant will be completely UAC-financed; present Norden facilities are leased.

Norden's fields of interest include aircraft, missile, and ship guidance; stabilization; communications; radar; closed-circuit TV; data handling; numerical control; and bomb director systems.

(Continued on page 200)



TYPE V1HJ-G8

Miniature Vane Axial Blower

Maximum air delivery in the smallest package

Combining a unique mechanical and aerodynamic design with EAD's standard, reliable 1" diameter motor has resulted in this extremely compact and efficient fan. In addition to the 2 pole characteristics listed below, EAD can supply 4 and 6 pole designs and models for operation from 1600-cycle and variable frequency power sources. Here is another development in the growing family of EAD V-Line vane axial blowers.

TYPICAL CHARACTERISTICS

115 Volt • 400 cycles single or three phase	1.5" total length
19,000 RPM nominal	1.990" housing diameter
65 CFM at 0" SP	Available with: 1. Leads
35 CFM at 2.3" SP	2. Terminals on mounting flange
Life in excess of 1000 hours at 125°C.	3. Terminals on housing

Write for complete technical data.

Magnetics, metallurgy, lubrication, insulation . . . these and other technologies have been advanced by progressive engineering and production personnel at Eastern Air Devices to make a science of "the act of turning." Since 1942, this scientific approach to the improvement and development of precision rotating devices has resulted in higher output efficiencies, reliable operation in higher ambients and superior performance characteristics under the most severe environmental conditions. In addition to continued product improvement, the application of this science has developed a number of firsts, including variable frequency motors, pure sine wave alternators and thermistor compensation of integrating tachometers. Combine this technical ability with high volume production, unsurpassed quality control, parts standardization for lower cost, and you can see why EAD has been specified by leading systems manufacturers for nearly two decades.

EASTERN AIR DEVICES, INC. EAD

Subsidiary of Norbute Corporation • Dover, New Hampshire

INDUCTION MOTORS • SERVO MOTORS • HYSTERESIS MOTORS
INTEGRATING TACHOMETERS AND MOTOR TACHOMETERS • BLOWERS
INERTIALLY DAMPED SERVO MOTORS • TORQUE MOTORS • FANS
DAMPING MOTOR TACHOMETERS • GEAR MOTORS • ALTERNATORS

CIRCLE 57 ON READER SERVICE CARD

BASIC BUILDING BLOCKS FROM KEARFOTT

Analog-to-Digital Converters

Kearfott's rugged shaft position-to-digital converters are resistant to high shock and vibration and high and low temperature environments. Ideally suited for missile applications, these converters are available for many uses, including latitude, longitude, azimuth or conventional angular shaft displacement conversion and decimal count conversion. Exclusive drum design provides large conversion capacity in smallest size. Combination counter converter assemblies for both visual and electrical readout also available.

TYPICAL CHARACTERISTICS

Kearfott Unit No.	P1241-11A
Code	Cyclic Binary
Range	0-32,768 (2^{15})
Bits per Revolution	16
Revolutions for Total Range	2,048
Volts D.C.	10.5
Current (ma.)	20
Inertia (gm. $cm.^2$)	20
Unit Diameter (in.)	1¼
Unit Length (in.)	3
Life	10^6 Revolutions or 10^3 hours
Static Torque (in.-oz.)	2 (break) 1 (running)
Weight (oz.)	5
Maximum Speed (RPM)	600

Write for new ADAC brochure.

BASIC BUILDING BLOCKS FROM KEARFOTT

20 Second Synchro

This synchro, just one of a broad line offered by Kearfott, provides the extreme accuracy required in today's data transmission systems. Kearfott synchro resolvers enable system designers to achieve unusual accuracy without the need for 2-speed servos and elaborate electronics. By proper impedance matches, up to 64 resolver control transformers can also operate from one resolver transmitter.

TYPICAL CHARACTERISTICS — SIZE 26

Type Resolver	Transmitter	Control Transformer
Part Number	Z5161-001	Z5151-003
Excit. Volts (Max.)	115	90
Frequency (cps)	400	400
Primary Imped.	400/80°	8500/80°
Secondary Imped.	260/80°	14000/80°
Transform. Ratio	.7826	1.278
Max. Error fr. E.Z.	20 seconds	20 seconds
Primary	Rotor	Stator

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT

Integrating Tachometers

Kearfott integrating tachometers, special types of rate generators, are almost invariably provided integrally coupled to a motor. They feature tachometer generators of high output-to-null ratio and are temperature stabilized or compensated for highest accuracy integration and rate computation. Linearity of these compact, lightweight tachometers ranges as low as .01% and is usually better than ± .1%.

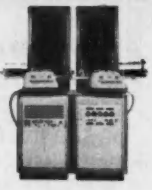
TYPICAL CHARACTERISTICS

	Size 11 (R860)
Excitation Voltage (400 cps)	115
Volts at 0 rpm (RMS)	.020
Volts at 1000 rpm (RMS)	2.75
Phase shift at 3600 rpm	0°
Linearity at 0-3600 rpm	.07
Operating Temperature Range	−54° +125°

Write for complete data.

Miniature Floated Gyro

Electrohydraulic Servo Valve



Scanalog 200-Scan Alarm Logging System

Engineers: Kearfott offers challenging opportunities in advanced component and system development.

Kearfott — A GENERAL PRECISION COMPANY

KEARFOTT COMPANY, INC., LITTLE FALLS, N. J.
A subsidiary of General Precision Equipment Corporation
Sales and Engineering Offices: 1500 Main Ave., Clifton, N. J.
Midwest Office: 23 W. Calendar Ave., La Grange, Ill.
South Central Office: 6211 Denton Drive, Dallas, Texas
West Coast Office: 253 N. Vinedo Avenue, Pasadena, Calif.

NOW AVAILABLE IN TRANSITRON'S NEW PACKAGE

SILICON CONTROLLED RECTIFIER

handling 10KW power

TYPE	MINIMUM PEAK REVERSE VOLTAGE (Volts)	MINIMUM FORWARD BREAKDOWN VOLTAGE (Volts)	MAXIMUM AVERAGE FORWARD CURRENT (amps) at T case = 100°C	MAXIMUM AVERAGE FORWARD CURRENT (amps) at T case = 25°C
TCR 102	100	100	10	20
TCR 202	200	200	10	20
TCR 302	300	300	10	20
TCR 402	400	400	10	20

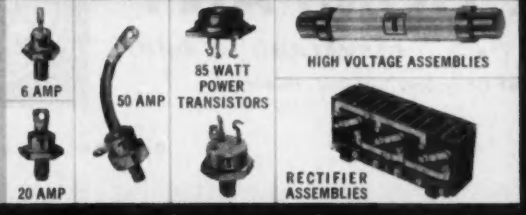
Maximum Storage Temperature Range — 65°C to +150°C
Maximum Operating Temperature Range — 65°C to +125°C
Send for Bulletin TE 1356

Transitron's Silicon Controlled Rectifier is a PNPN high power bistable controlled switching device. It is analogous to a thyratron or ignitron, with far smaller triggering requirements and microsecond switching. The low forward voltage drop permits high current ratings and provides high efficiency with low cooling requirements. The PNPN design permits higher voltage ratings and lower saturation resistance than power transistors. This permits the smallest packaging for high power control yet made possible.

Ratings currently available extend to 10 amperes at 100°C case temperature and up to 400 volts forward and inverse ratings. *Operation at 125°C is now permissible with derating.* Full ratings are possible at 35°C ambient with a 5" square heat sink. The peak control power is typically 1/200,000 of the output power!

Transitron's Silicon Controlled Rectifier has been designed into a new package for more rugged, convenient, and practical application. The 11/16" hex base and the general outline coincide with EIA standards for the 20-ampere rectifier.

OTHER TRANSITRON SILICON PRODUCTS FOR HIGH POWER USE



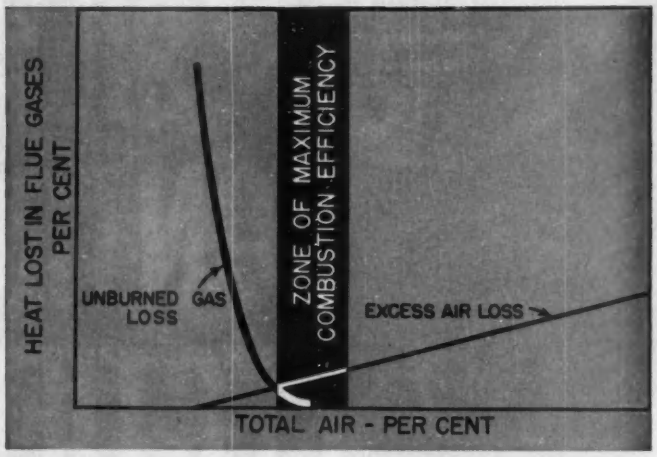
Transitron electronic corporation
wakefield, massachusetts

How to get maximum combustion efficiency . . . measure both combustibles and oxygen

Simultaneous measurement of both oxygen and combustibles is needed to obtain optimum combustion. No instrument that measures only one of these two interdependable factors can give you the full information necessary.

Now, Bailey offers two units, each giving a continuous and simultaneous double check on combustion efficiency: a permanent analyzer-recorder which records both factors on a single chart; and a new light weight, portable unit which indicates both factors.

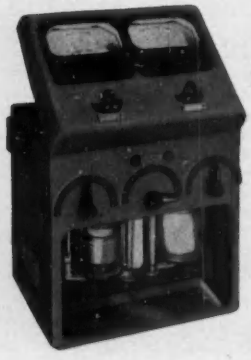
Both instruments measure: (1) excess air—regardless of the fuel or combinations of fuel being burned, (2) mixing efficiency of your fuel burning equipment by showing per cent combustibles in the flue gas.


HEAT LOST IN FLUE GASES PER CENT
UNBURNED GAS LOSS
ZONE OF MAXIMUM COMBUSTION EFFICIENCY
EXCESS AIR LOSS
TOTAL AIR - PER CENT

Maximum Combustion Efficiency is secured by keeping the sum of Excess Air Loss and Unburned Gas Loss to a minimum. To do so by the direct method simply measure both oxygen and combustibles in flue gas.

Both units are designed to increase efficiency in the furnace operations of the steel industry, on glass tanks, cement and lime kilns, ceramic and refractory kilns, steam boilers and also on direct and indirect-fired furnaces in the metal processing industries. To prevent your money from becoming waste gas, look into these two efficiency provers. A Bailey engineer will be glad to give you details or write us for product specifications.

For portable use—
HEAT PROVER Analyzer



The famous Cities Service HEAT PROVER analyzer is now Bailey built and sold. Weighing only 25 pounds, it is a self-contained automatic analyzer including a sampling tip and hose plus a thermocouple for temperature measurement.

Instrument dials are dual range for greater accuracy and sensitivity.

For permanent installation
Oxygen-Combustibles Recorder

The Bailey Oxygen-Combustibles Analyzer-Recorder coordinates both records on one chart. These records enable the operator to keep fuel burning equipment performing continuously in the zone of maximum combustion efficiency. Excess air may be reduced to the point where combustibles begin to show.

G 40-1

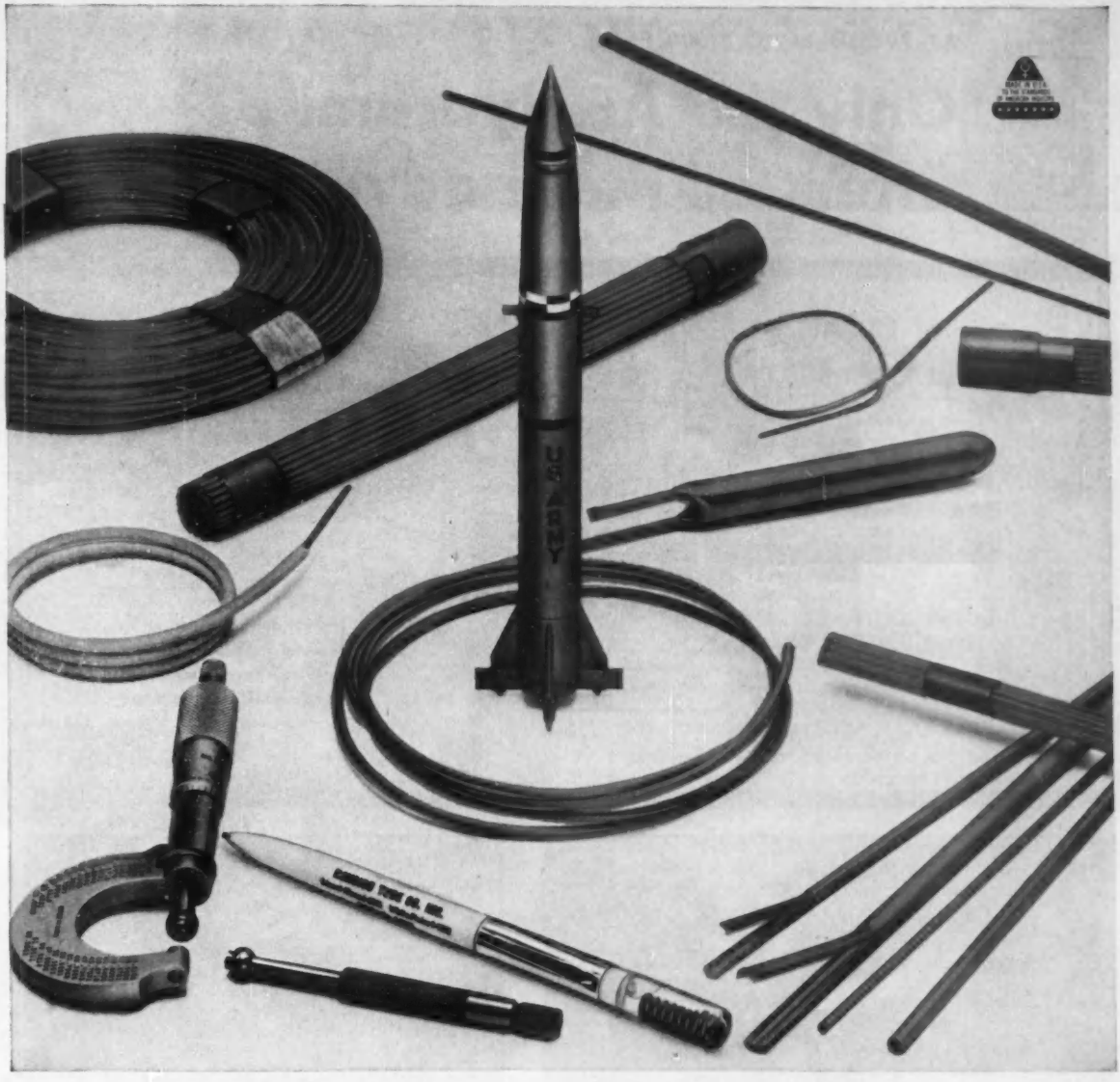
Instruments and controls for power and process

BAILEY METER COMPANY

1079 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

BAILEY METERS



EVER REALLY EXPLORE INNER SPACE?

Inner space of copper Capillary and Restrictor Tubing, that is? Especially that used for instrumentation and controls? Kensico recently asked an independent consulting service to explore the inner space of its small-diameter, *precision-drawn* tubing in comparison with leading competitive products. Some mighty revealing discoveries were made by using *photomicrography!* Interested control engineers may obtain a set of these photomicrographs—or Free Flow Charts and engineering consultation—by simply calling, writing or wiring Gordon Edwards at the Mt. Kisco plant.

We also make hard and soft copper water tube . . . copper air conditioning and refrigeration tubes . . . copper tubing for propane gas lines, heat exchangers, automotive and industrial applications.

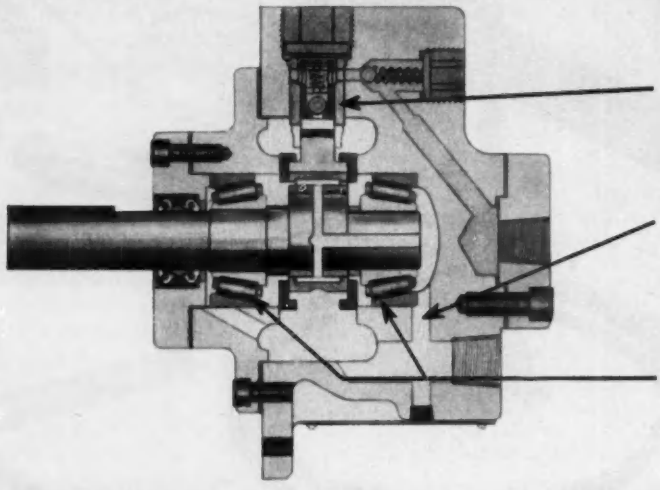
CAMBRIDGE, MASS. • MIDDLEBURY, CONN. • BUFFALO, N. Y. LINDENHURST, N.Y. • GOSHEN, N.Y. • ROSELLE, N.J. • PHILADELPHIA, PA. • FLOURTOWN, PA. • PITTSBURGH, PA. • CLEVELAND, OHIO DETROIT, MICH. • EVANSTON, ILL. • ST. LOUIS, MO. • MILWAUKEE, WISC. • DURHAM, N.C. • FT. LAUDERDALE, FLA. • ST. PETERSBURG, FLA.

Kensico Tube
COMPANY INCORPORATED, MT. KISCO, N. Y.

CIRCLE 61 ON READER SERVICE CARD 61

AT PRESSURES TO 5,000 PSI . . .

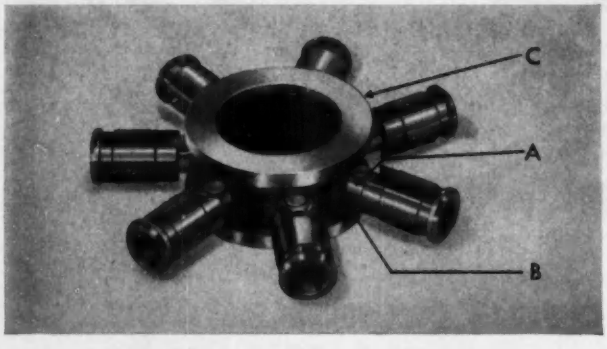
Only the AE Hydramite offers all these advantages



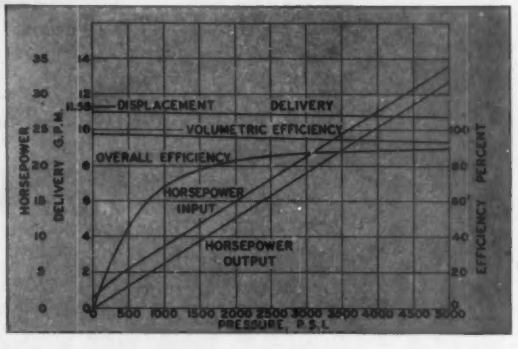
Liners and plungers are honed and individually mated for optimum fit.

Low friction losses. Pump operates with case flooded. Oil is ported to take advantage of natural pumping action of tapered bearings.

Heavy duty, high capacity tapered roller bearings absorb more punishment . . . handle maximum unbalanced loads . . . last longer.

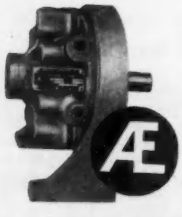


Positive pumping action. The Hydramite has no cam follower springs to fail. Plungers (A) are connected to curved slippers (B) which are held against the outer race of cam shaft needle bearing by two plunger return rings (C). As the shaft revolves, each plunger is pushed outward in succession and then pulled inward by the return rings.



High efficiency. With a Hydramite you get an overall efficiency of 85%. Its flat overall high efficiency curve has little variation between 1,500 and 5,000 psi. What's more with a Hydramite you get positive suction. There is no requirement for supercharging equipment which deducts from system efficiency.

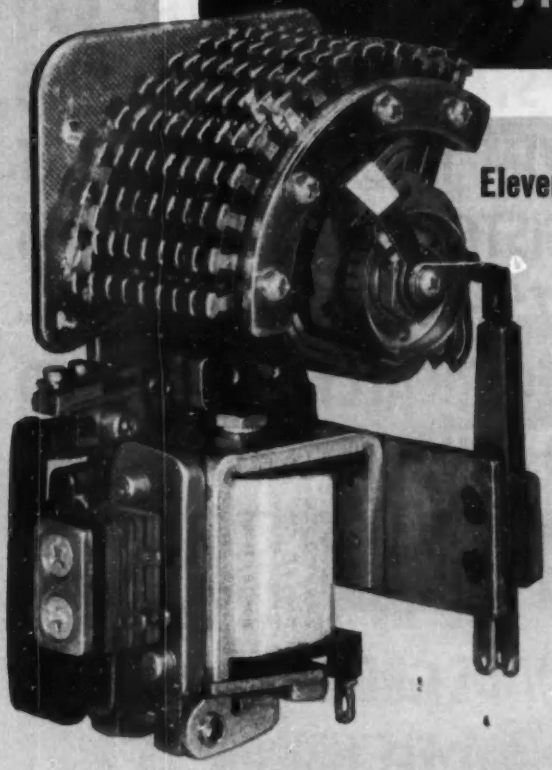
To meet your specific requirements, Hydramite pumps can be supplied for constant displacement from 3 to 30 gpm at 5,000 psi and 70 to 85 gpm at 3,000 psi for hydraulic fluids with viscosities of 150 to 300 ssu at 100° F. In special applications they have handled viscosities as low as 40 and as high as 900 ssu at 100° F. Special materials and seals permit handling of missile fuels and special fluids at higher temperatures. Available in flange, foot or face mounted styles. Write or call American Engineering Company, Philadelphia 37, Pennsylvania. Phone: Cumberland 9-3800.



AMERICAN ENGINEERING COMPANY

Hele-Shaw Pumps, Lo-Hed Hoists, AE Marine Deck Auxiliaries, Vibra Grate, Perfect Spread and Taylor Stokers.

CLARE ANNOUNCES THE Type 211 Stepping Switch



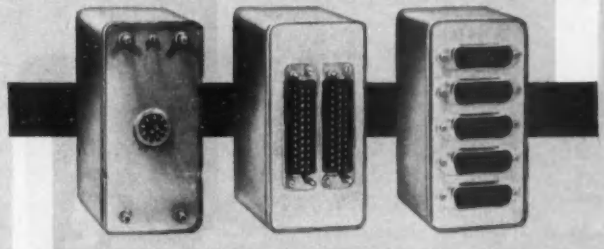
Eleven-point stepping switch has 12-level capacity, 100,000,000-step* life

Many new, improved features give this Clare Type 211 springdriven stepping switch longer service life, greater capacity and a freedom from maintenance hitherto unknown in an 11-point switch. Rugged, compactly built, the 211 is available with a variety of enclosures and mounting assemblies to meet a wide range of design applications.

LONGER LIFE EXPECTANCY—This new switch has a life expectancy of from 100 million steps at twelve levels to 300 million steps at three levels with proper relubrication and readjustment.

GREATER STEP CAPACITY—Up to twelve 11-point levels or four 33-point levels enable it to handle complex switching, counting, totalizing, selecting, and sequence control operations.

SIMPLIFIED MAINTENANCE—Fewer moving parts, due to the elimination of pawl bearings, and a more rigid armature arm simplify maintenance and increase service life.



VARIETY OF ENCLOSURES—Hermetically sealed enclosures, filled with nitrogen or oil, are available with hook-type solder terminals. Dust cover enclosures are available with miniature or standard Amphenol Blue Ribbon connectors.

Write for bulletin CPC-3 to C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Ltd., P. O. Box 134, Downsview, Ontario. Cable Address: CLARELAY.

TYPE 211 SWITCH—ELECTRICAL DATA

OPERATING SPEEDS—Self-interrupt speed: 60 SPS at 25°C on nominal voltage. Remote impulse speed: 30 SPS at 25°C on nominal voltage with 66⅔% make impulse.

OPERATE & RELEASE TIME—Operate time: 20 ms at 25°C on nominal voltage. Release time: 10 ms at 25°C on nominal voltage.

OPERATE & RELEASE VOLTAGE—Maximum pull-in at 25°C is 66% of nominal voltage. Minimum dropout at 25°C is 5% of nominal voltage.

BREAKDOWN TEST—1000 v, rms, 60 cps, is standard.

COILS—Coil resistances for typical voltages are shown below:

Voltage Vdc	1-8 Levels Ohms	9-12 Levels Ohms
6	1.5	1.5
12	6	6
24	24	20
48	100	70
60	150	100
110	600	400

TYPE 211 SWITCH—MECHANICAL DATA

OVERALL DIMENSIONS—Length (maximum)—4-5/16 in. Height (1C interrupter, 1C O.N.S.)—2¾ in. Width—from 1-5/16 in. for 3 levels to 2-13/16 in. for 12 levels.

NET WEIGHT—From one pound for 3 levels to 1½ pounds for 12 levels.

BANK CONTACT—Standard is phosphor bronze. Also available are coin silver or gold plated phosphor bronze.

MAXIMUM BANK LEVELS & PILEUPS

Type of operation (points)	11	33
Bank levels maximum (electrical)	12	4
Interrupter springs	6	6
Off-normal springs	6	6
Number of ratchet teeth	33	33

WIPERS—Standard wipers are non-bridging phosphor bronze with coin silver and gold plated phosphor bronze available in either non-bridging or bridging models.

CLARE RELAYS

FIRST in the Industrial Field

CIRCLE 63 ON READER SERVICE CARD

THE PRACTICAL LOW COST ANSWER TO MULTI-CHANNEL OSCILLOGRAPHIC RECORDING PROBLEMS ··· SANBORN INTRODUCES THE FIRST OF THE 950 SERIES ··· THE 950-1500 SYSTEM ··· FOR FLOATING OR GROUNDED INPUTS FROM 10 μV TO 0.1 VOLT PER DIVISION ··· ALL-TRANSISTORIZED ELECTRONICS MOUNTED BEHIND A SINGLE 7" HIGH PANEL ··· FLUSH-FRONT RECORDER WITH 9 ELECTRICALLY-CONTROLLED CHART SPEEDS ··· IMPROVED, RUGGED GALVANOM-ETERS ··· CLEAR, INKLESS TRACES ··· RECTANGULAR COORDINATE RECORDINGS ··· ALL IN A SYSTEM DE-SIGNED SPECIFICALLY TO PROVIDE GREATER ECONOMY AND ACCURACY WHEN SYSTEM FLEXIBILITY IS NOT REQUIRED.

Additional features of the 950-1500 include: common power supply, built-in MOPA, front and rear inputs, easily serviced plug-in circuit cards, adaptability for use with other readout devices. When many channels are constantly in use for floating or grounded high gain inputs the simplified 950-1500 design assures dependable operation, yet at much lower "per channel" cost.

Complete details are available from Sanborn Sales-Engineering Representatives located in principal cities throughout the U.S., Canada and foreign countries.

SPECIFICATIONS

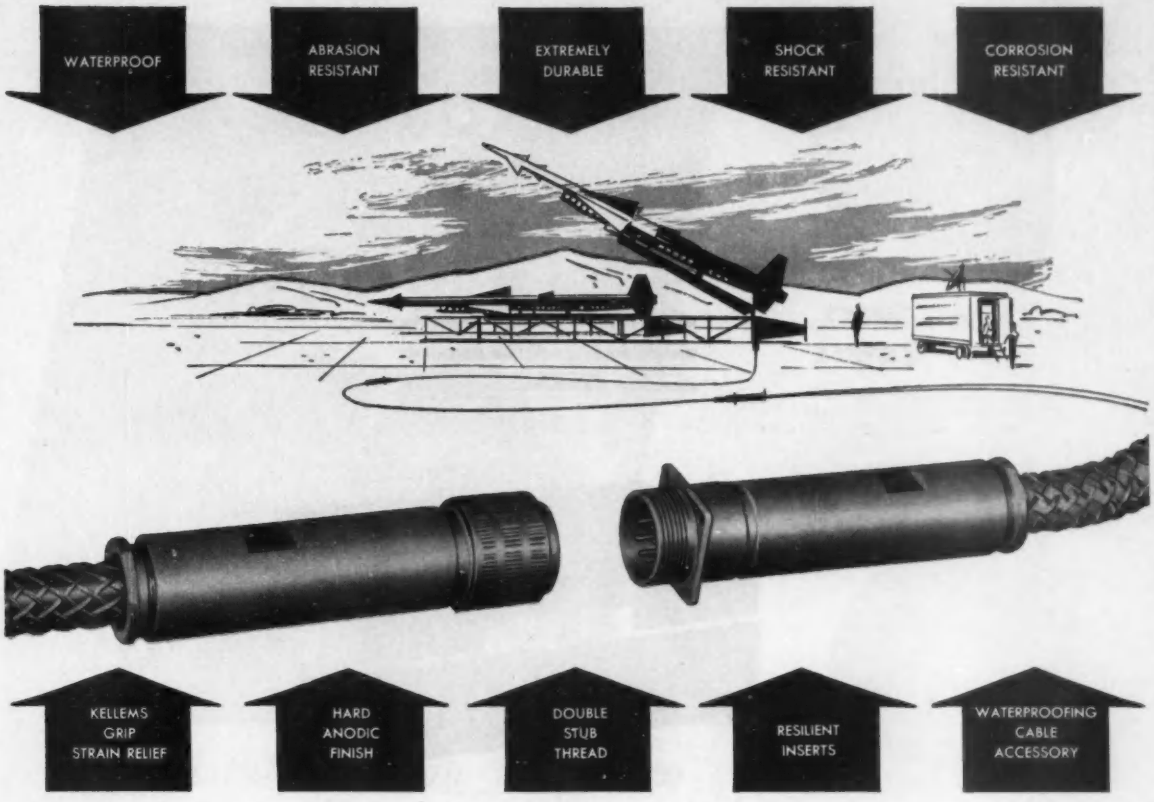
INPUT	100,000 ohms, all ranges, floating and guarded.
OUTPUT	400 ma. full scale, 15 ohms nominal load, ungrounded
LINEARITY	±0.4%
SENSITIVITY	10, 20, 50, 100, 200, 500, 1000 and 2000 uv per chart div
COMMON MODE REJECTION	100 db, min. dc
FREQUENCY RESPONSE	0-100 cps within 3 db at 10 div peak to peak. 0-50 cps within 3 db at 50 div peak to peak.
NOISE	¼ div peak to peak maximum.

(All data subject to change without notice)

NEREM '59 Comm. Armory, Boston, November 17, 18, 19.

SANBORN COMPANY

INDUSTRIAL DIVISION 175 Wyman Street, Waltham 54, Massachusetts



Why it pays you to specify

BENDIX QWL ELECTRICAL CONNECTORS FOR USE WITH MULTI-CONDUCTOR CABLE

Used extensively on ground launching equipment for missiles and on ground radar, and other equipment, the Bendix* QWL Electrical Connector meets the highest standards of design and performance.

A heavy-duty waterproof power and control connector, the QWL Series provides outstanding features:

- The strength of machined bar stock aluminum with shock resistance and pressurization of resilient inserts.
- The fast mating and disconnecting of a modified double stub thread.
- The resistance to loosening under vibration provided by special tapered cross-section thread design. (Easily hand cleaned when contaminated with mud or sand.)
- The outstanding resistance to corrosion and abrasion of an aluminum surface with the case hardening effect of Alumilite 225 anodic finish.
- The firm anchoring of cable and effective waterproofing provided by the cable-compressing gland used within the cable accessory.
- The watertight connector assembly assured by neoprene sealing gaskets.
- The additional cable locking produced by a cable accessory designed to accommodate a Kellems stainless steel wire strain relief grip.
- Prevention of inadvertent loosening insured by a left-hand accessory thread.
- The high current capacity and low voltage drop of high-grade copper alloy contacts. Contact sizes 16 and 12 are closed entry design.

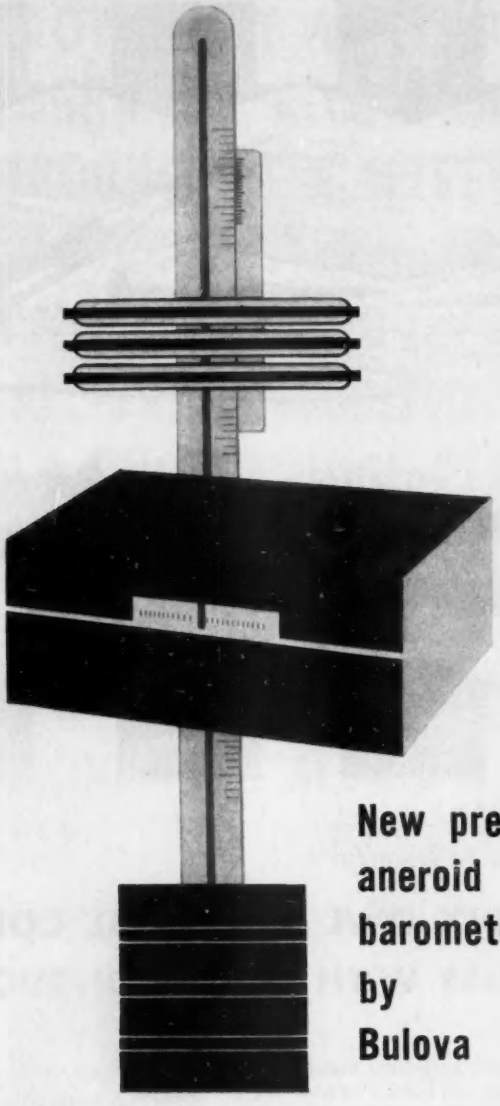
These are a few of the reasons it will pay you to specify the Bendix QWL electrical connector for the job that requires exceptional performance over long periods of time.

*TRADEMARK

Export Sales and Service: Bendix International Division, 205 E. 42nd St., New York 17, N.Y. Canadian Affiliate: Aviation Electric Ltd., 200 Laurentien Blvd., Montreal 9, Quebec. Factory Branch Offices: Burbank, Calif.; Orlando, Florida; Chicago, Ill.; Teaneck, New Jersey; Dallas, Texas; Seattle, Washington; Washington, D. C.

Scintilla Division
SIDNEY, NEW YORK

Bendix
AVIATION CORPORATION



New precision aneroid barometer... by Bulova

Bulova barometer sensitive to 0.001" Hg

The Bulova Precision Barometer has advantages over the best mercury types. Easy-to-read tape presents pressure between 21 and 31 inches in thousands. Maximum error: within 0.002"; instrument lag: 0.001" maximum over 3" range.

The Bulova capability—in Research & Development, electronics, and precision production—is ready to support your effort, regardless of its scope.

Experience in precision design and manufacture is the Bulova tradition—the Bulova capability—it has been for over 80 years. For more information write:

Industrial & Defense Sales, 62-10 Woodside Avenue, Woodside 77, N.Y.

BULOVA

66 CIRCLE 66 ON READER SERVICE CARD

CIRCLE 67 ON READER SERVICE CARD→

It takes Tough Testing to build Timing Performance

When you buy a Haydon Timing Motor or Timing Device, you buy high quality and superior performance, because every production model and every new design has *proved* itself by passing the toughest, most exhaustive series of tests that our engineers can devise.

Quality control at Haydon starts with a careful inspection of all in-coming materials. It continues throughout production — with all parts and assemblies gaged, inspected or physically tested after every operation that can affect the performance of the finished motor or device. Final step is an inspection of completed motors and timing devices. All units are performance tested for many hours under varying conditions and are checked for quiet operation. Percentage samples of each lot are checked for torque rating, timing accuracy, and accuracy and alignment of gears and shafts. In addition, all new designs and periodic samplings from production are subjected to special "life endurance" tests in which hundreds of units are run continuously under various load conditions. In some instances, units have now been running ceaselessly for more than 10 years . . . proving their ability to perform *millions of cycles without failure!*

When you submit your timing problems to Haydon, you can be certain that our teams of engineers and other Timing Specialists have the experience, knowledge and facilities to supply devices designed, produced *and* tested to meet your needs exactly and perform according to your specifications.

For further information, write now, outlining your timing requirements.

Haydon
AT TORRINGTON

DIVISION OF GENERAL TIME CORPORATION

2335 **EAST ELM STREET**
TORRINGTON, CONNECTICUT

Headquarters for Timing

TIME
TIMER

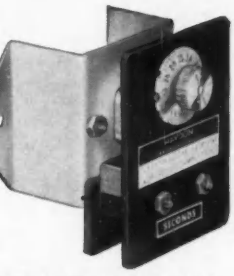
Provides time up to 9.5 min such applicati protection of p and/or operati operating cycle 120 or 240 volt, cycle current.

400 C
MOTO

These split p provide the m accurate appro control for mi applications. R 3,000 RPM at 4 volt normal. Tu available — Hea 18 gram millime the rotor, and th with 5 gram milli the rotor. These m be applied to Hayd trains if desired.

CYCLE TI

These units repeat or sequence of oper long as the motor is Available in a wide speeds, a broad rang timing intervals, and wide range of enclose pole, double throw su for 120 and 240 volt o for 50 and 60 cycles.



TIME DELAY TIMER

rovides time delay in ranges
to 9.5 minutes. Ideal for
ch applications as the
tection of power tubes
/or operating preset
rating cycles. Available in
or 240 volt, 50 or 60
current.

400 CYCLE MOTOR

hese split phase motors
ovide the military an
curate approach to timing
trol for military
lications. Rotor speed is
0 RPM at 400 cycles, 115
normal. Two models are
lable — Heavy Duty with
am millimeters torque at
otor, and the Miniature
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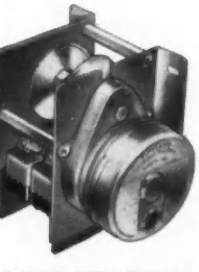
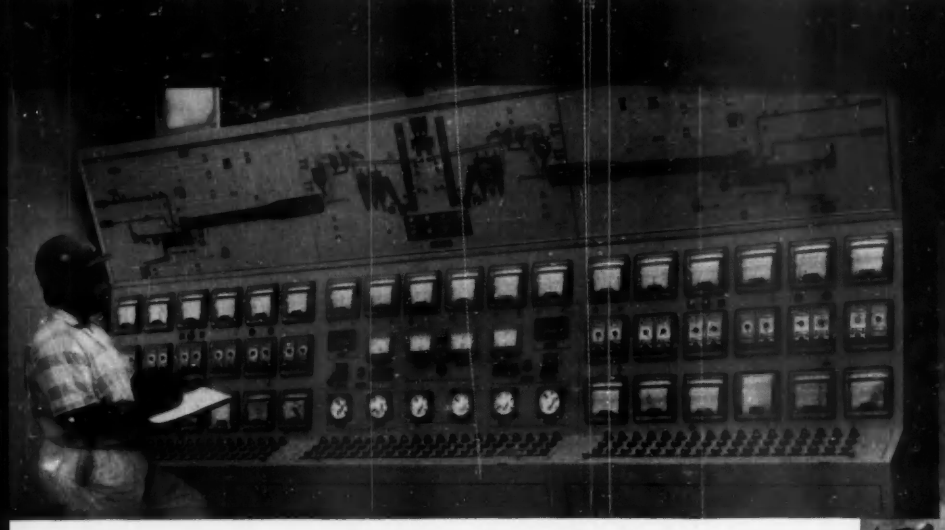
tor. These motors may
lied to Haydon gear
if desired.



CLE TIMER

units repeat a set cycle
ence of operations as
the motor is energized.
le in a wide choice of
broad range of
tervals, and with a
ge of enclosed single
ble throw switches
d 240 volt operation,
60 cycles.

an electronic control success story every process engineer will want to read...



Riverside's computer-controlled plant now on-stream with Foxboro Electronic Consotrols

pressures — temperatures — flows all electronically controlled

Giant, gas-fired cement kilns, 310′ long, 10′ and 12′ in diameter — they're under complete Foxboro electronic control at Riverside Cement Company, Oro Grande, Calif. All process variables, including pressures, temperatures, motion, differential pressures, motor speeds, gas-analysis, and gas-air ratios are included in this fully co-ordinated instrument system.

Riverside's Electronic Consotrol* Instrumentation includes transmitters, controllers, recorders, converters, integrators, alarms — all solid-state — all linked by a common 10-50 ma, d-c signal. Transmission is over simple, unshielded lines. And this ultra-modern control system is fully compatible with process control computers.

Foxboro Electronic Consotrol Instrumentation is ideal for chemical plants, refineries, steel mills, nuclear reactors — wherever precise, rapid, long-distance control is required. Ask your local Foxboro Field Engineer about Electronic Consotrols — or write for Bulletin 21-10. The Foxboro Company, 8511 Neponset Avenue, Foxboro, Mass.

*Reg. U. S. Pat. Off.

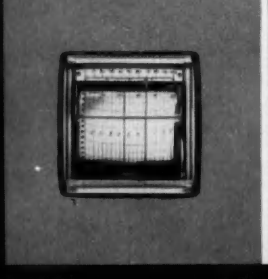
AN ELECTRONIC CONSOTROL INSTRUMENT FOR EVERY CONTROL LOOP

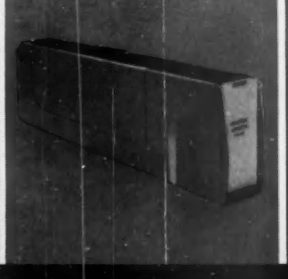
Recorders
No amplifiers, slidewires, or servo motors. Operate completely independent of controller. 1 and 2-pen models, with 4" vertical strip chart.

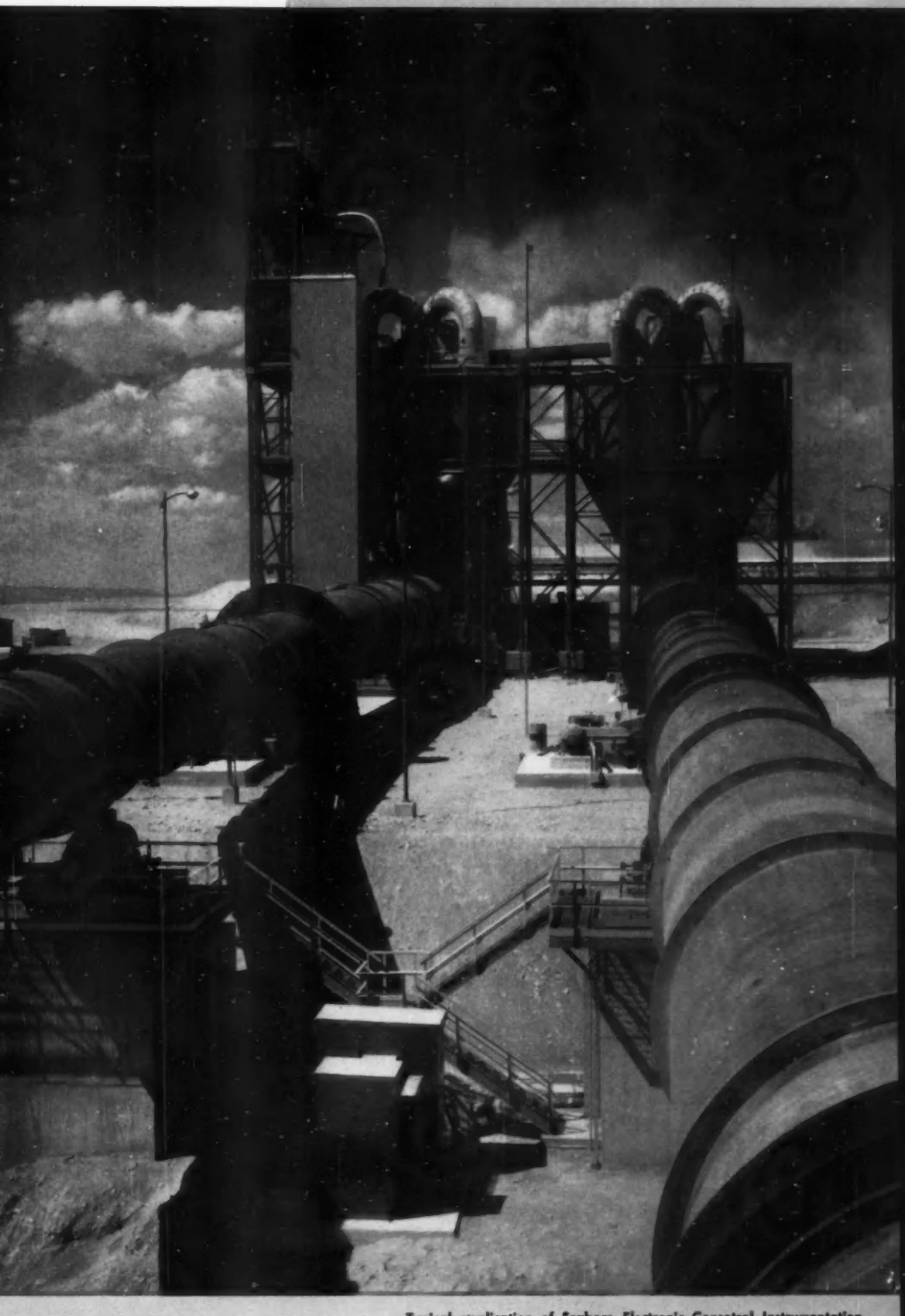
Indicating Transmitters
Use any standard Foxboro measuring element — continue to measure and indicate even in event of power failure.

Electrical Converters
Convert EMF and Resistance measurements to a 10-50 ma, d-c signal. Rack or panel mounted. No batteries, no slidewires, no servos.

2-wire Transmitters
For measurements such as pressure, absolute pressure, differential pressure, and lev
Require no local power supp







OL LOOP FUNCTION

nitters
ents such as pres-
e pressure, dif-
ssure, and level.
cal power supply.

Indicating Controllers
May be mounted individually or in same housing with recorder. Each operates and pulls out from panel — completely independent of the other.

Typical application of Foxboro Electronic Consotrol Instrumentation . . . Riverside Cement Company's modern plant at Ora Grande, Calif. 310′ kilns have all process variables under Foxboro electronic control. Other major Foxboro electronic installations include petrochemical plants in the U. S. and Canada, nuclear reactors, as well as unattended booster stations on a 680-mile crude oil pipe line.

FOXBORO

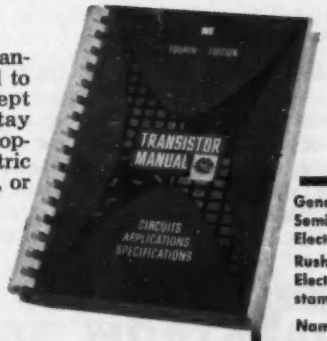
REG U.S. PAT OFF

Test your Transistor I.Q. with this quick quiz:

1. What are the six main types of transistor computer logic?
2. What are the methods for servicing and aligning a transistor radio?
3. How is a transistor bias circuit designed taking into account variations of beta, I_{CO}, V_{BE} and temperature?
4. How are common base h parameters converted to common emitter h parameters?
5. What is the difference between an alloy diffused transistor and a drift transistor?
6. What circuit can be used for a 2 KW regulated power supply using silicon controlled rectifiers?
7. What circuit can be used for a transistor sawtooth generator with a 0.3% linearity?
8. Can a simple bass-boost circuit be designed to compensate for changes in output level of a phono preamplifier without lowering its sensitivity?
9. What are the major factors influencing transistor reliability?
10. What is the collector leakage current in a common emitter transistor when the base is reverse biased?

If you can't answer all of these questions, don't be discouraged. Help is at hand! Just get yourself a copy of the big new 4th Edition of General Electric's famous TRANSISTOR MANUAL. Its 227 fact-filled pages contain the answers to all these questions—and many, many more. There are 60 more pages, 7 more chapters and 23 additional circuits!

This is the one book in the transistor field you can't afford to be without—constantly kept up-to-date to help you stay abreast of the latest developments. Your General Electric Tube Distributor has them, or mail the coupon at right.



General Electric Company
Semiconductor Products Dept., Section S24119
Electronics Park, Syracuse, N. Y.

Rush me the enlarged 4th Edition of General Electric's Transistor Manual. I enclose $1.00. (No stamps, please.)

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←CIRCLE 70 ON READER SERVICE CARD

CIRCLE 71 ON READER SERVICE CARD 71

pared down to fit where others can't... size 5 motor generators

Size 5 Motor Generators are now a reality! Servo engineers working against extreme space and weight limitations can specify the ultimate in miniaturization—*Daystrom Transicoil.* Weighing a mere 1.1 oz, these Size 5's develop a minimum stall torque of 0.11 oz-in and have a free speed of 10,000 rpm. Units are available for 400 cycle operation with 26 or 33 control phase winding. The control phase is split for operation directly with transistor amplifiers.

Complete specifications with drawings and graphs of performance characteristics are yours for the asking. Other types and sizes of motors and motor generators are also available. And be sure to get complete details on our new synchro line. Daystrom Transicoil, Division of Daystrom, Inc., Worcester, Montgomery County, Pa. Phone: JUno 4-2421. In Canada: Daystrom, Ltd., 840 Caledonia Rd., Toronto 19, Ont. Foreign: Daystrom International Division, 100 Empire Street, Newark 12, N. J.

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Representatives in Canada and Other Foreign Countries

New Money Makers for Industry:

KIN TEL CLOSED CIRCUIT TV SYSTEMS

what they are, and what they can can do for you...

What is a KIN TEL Closed Circuit TV system?

The basic closed circuit television system manufactured by KIN TEL consists of a camera, a camera control unit and a monitor (receiver) each connected by cable. The camera can be located at great distances from the monitor, and any combination of cameras and monitors can be used.

The camera is small enough to hold in your hand; rugged enough to operate in 150° F. without a protective housing; sensitive enough to provide excellent pictures of objects illuminated by only a candle.

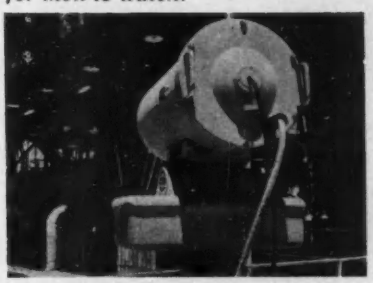
The camera control provides automatic operation. The system is continuously self-adjusting for wide variations in light levels (several thousand to one), and features automatic high definition of bright objects. The only control you have to touch is the on-off switch.

The monitor displays a crisp, clear picture...full 650-line resolution, twice that of the best home TV reception.

How are such systems used?

Today, KIN TEL closed circuit TV systems are performing a number of jobs for *hundreds* of firms, safely, inexpensively, tirelessly.

They are being used to watch operations or events that are tedious, difficult, dangerous, or even impossible for men to watch.



For example: Convair (above), Douglas, Lockheed and Northrop watch rocket tests with KIN TEL systems. U.S. Steel uses one to see inside open hearth furnaces. Westinghouse watches nuclear power reactor tests with one.

They are being used for surveillance.

For example: The San Francisco Naval Shipyard uses one to guard against pilferage.

They are being used for traffic control.

For example: The Alameda Naval Air Station uses a KIN TEL TV system to observe aircraft landings on the portion of the runway that is not visible from the control tower.

They are being used to transmit visual information quickly and accurately; for remote observation of charts, meters, graphs, schedules, blueprints, photographs, images from microscopes, fingerprints, signatures...the list is almost endless.

For example: E. F. Hutton uses a KIN TEL system to transmit stock market quotations to the offices of the firm's executives. The Los Angeles Department of Water and Power uses one for remote viewing of water-level meters. The University of California teaches physics with one.

They are being used for monitoring any operation that normally requires standby personnel.

For example: American Potash and Chemical (above) monitors conveyor line and warehousing operations with a KIN TEL TV system.

Why do these firms choose a KIN TEL system?

For a variety of reasons.

First, *reliability.* KIN TEL TV is designed for continuous duty operation in severe environments. Day in and day out, it keeps working. It's the first choice for ICBM and other missile programs that really depend on TV, that can't chance failure, that can't afford to compromise with reliability.

Second, *picture quality.* KIN TEL TV presents clear, sharp pictures. Full 650-line resolution provides maximum data...essential for *quantitative* observation of complex operations or transmission of printed material.

Third, *automatic operation.* KIN TEL TV is the only closed circuit system that provides entirely automatic, through-the-lens compensation for light-level changes of several thousand to one.

Fourth, the KIN TEL closed circuit TV system is extremely *sensitive.* The light required to read this page is enough for sharp clear pictures, and usable pictures can be provided with less than one-foot candle illumination.

Fifth, KIN TEL TV systems are *easy to install* and *simple to operate.* With no changes in lens iris to make, with no difficult, interacting electrical adjustments required, the only thing the operator has to know is the location of the on-off switch.

Sixth, a *complete* line of shelf-item system components and a variety of cameras and monitors make virtually any application feasible...permit observation of nearly every kind of operation, under all kinds of conditions.

For example, with system components, you can remotely position the camera, remotely select one of several lenses, remotely "zoom" in or out for closeup or wide-angle viewing, operate the camera in extremes of temperature or in explosive or dusty atmospheres, view microscope images. Whatever your viewing problem, KIN TEL probably has a *stock* solution.

Seventh, you don't have to waste your time and money on application engineering. At no obligation to you, KIN TEL'S nationwide factory-trained field engineers – thoroughly experienced in optics, environmental requirements, lighting, cabling, human engineering factors, and other installation considerations–can determine whether or not closed circuit TV can be put to profitable use in your intended application.

What can a KIN TEL system do for your business?

It can do what it is doing right now for hundreds of other firms. It can save you time and money...increase efficiency...better your service to clients and customers. To find out how, write direct for catalog 6-103 and the name of your nearest KIN TEL engineering representative.

KIN TEL
A DIVISION OF
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ELECTRONICS, INC.

5725 Kearny Villa Road, P. O. Box 623, San Diego 12, California, BRowning 7-6700

KIN TEL–pioneer and leader in closed circuit television.

There's No End To It!

A Fenwal Continuous-Line Over-Heat Detector provides maximum "hot spot" protection

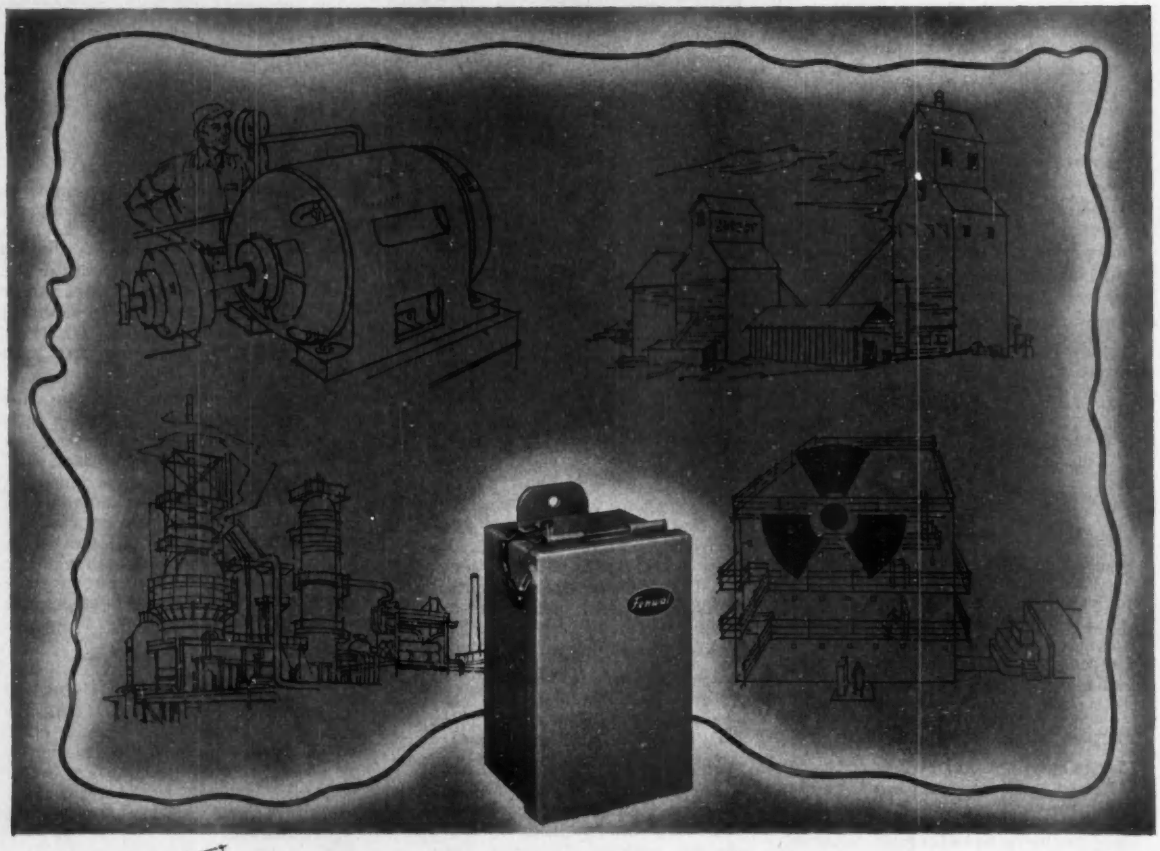
Hot as blazes, or just simmering, *any* undesirable temperature is quickly spotted by a Fenwal Over-Heat Detector. No individual sensors with resultant "dead spots." It's a discrete-sensing (non-averaging) system. Heat impinging at any point on sensing line triggers the alarm. *That's complete coverage!*

Line mounts easily — forms continuous loop back to compact control unit. Separate, connected lengths, set for different temperatures can operate independently. Rugged, solid-state design provides constant, fast-acting protection . . . requires no resetting. *A positive, trouble-free system!*

The Fenwal Over-Heat Detector has proved itself everywhere in aircraft and missiles. It's equally applicable in industry: on bearings, in grain storage areas, in catalyst beds and other petrochemical processing units. *There's no end to its uses!*

Your processing operations would be *better protected* at many points with Fenwal Line Temperature Detectors. Talk over your application with a Fenwal Sales Engineer. Write Fenwal Incorporated, 2911 Pleasant Street, Ashland, Mass.

Alarm connects directly to control unit of the Fenwal Continuous-Line Over-Heat Detector at point of protection; or by simple wiring at centralized panel. Sensing lengths available for temperatures from 255° to 1200°F.



ANOTHER EXAMPLE OF HOW **Fenwal** CONTROLS TEMPERATURE . . . PRECISELY

RCA SILICON RECTIFIERS

DIFFUSED-JUNCTION TYPES

Another Way RCA Serves You Through Electronics

RCA TYPES FOR INDUSTRIAL and MILITARY POWER SUPPLIES

	MAXIMUM RATINGS Absolute-maximum values: For supply frequency of 60 cycles and with resistive or inductive load.									CHARACTERISTICS		
				FORWARD CURRENT, DC				AMBIENT TEMPERATURE		At Ambient Temp. of 25°C		At Ambient Temp. of 100°C
RCA TYPE NUMBERS	Peak Inverse Voltage (VOLTS)	RMS Supply Voltage (VOLTS)	DC Reverse Voltage (VOLTS)	50°C Ambient (MA)	100°C Ambient (MA)	150°C Ambient (MA)	Surge One-Cycle (AMP)	Operating (°C)	Storage (°C)	Max. Forward Voltage Drop (DC) at Indicated DC Forward Current (VOLTS)	Max. Reverse Current (DC) at Max. Peak Inverse Voltage (μa)	Max. Reverse Current (averaged over one complete cycle) at Max. Peak Inverse Voltage (μa)
IN538	50	35	50	750	500	250	15	−65 to +165	−65 to +175	1.1 at 500 ma	5	400
IN537	100	70	100	750	500	250	15	−65 to +165	−65 to +175	1.1 at 500 ma	5	400
IN538	200	140	200	750	500	250	15	−65 to +165	−65 to +175	1.1 at 500 ma	5	300
IN539	300	210	300	750	500	250	15	−65 to +165	−65 to +175	1.1 at 500 ma	5	300
IN540	400	280	400	750	500	250	15	−65 to +165	−65 to +175	1.1 at 500 ma	5	300
IN1095	500	350	500	750	500	250	15	−65 to +165	−65 to +175	1.2 at 500 ma	5	300
IN547	600	420	600	750	500	250	15	−65 to +165	−65 to +175	1.2 at 500 ma	5	350
RCA TYPES FOR MAGNETIC AMPLIFIERS and BLOCKING CIRCUITS												
IN440-B	100	70	100	750	500	250	15	165	−65 to +175	1.5 at 750 ma	0.3	100
IN441-B	200	140	200	750	500	250	15	165	−65 to +175	1.5 at 750 ma	0.75	100
IN442-B	300	210	300	750	500	250	15	165	−65 to +175	1.5 at 750 ma	1.0	200
IN443-B	400	280	400	750	500	250	15	165	−65 to +175	1.5 at 750 ma	1.5	200
IN444-B	500	350	500	650	425	0	15	150	−65 to +175	1.5 at 750 ma	1.75	200
IN445-B	600	420	600	650	400	0	15	150	−65 to +175	1.5 at 750 ma	2.0	200

RCA TYPES FOR TV and RADIO RECEIVERS and GENERAL PURPOSE

	MAXIMUM RATINGS Absolute-Maximum Values: for supply frequency of 60 cps and with capacitor input to filter							CHARACTERISTICS				
			FORWARD CURRENT (UP TO 75°C)			AMBIENT TEMPERATURE		At Ambient Temperature of 25°C			At Ambient Temperature of 100°C	
								Max. Instantaneous Forward Voltage at Instantaneous Forward Current = 15 amps (VOLTS)	Max. Reverse Current (μa)		Max. Reverse Current (ma)	
RCA TYPE	Peak Inverse Voltage (VOLTS)	RMS Supply Voltage (VOLTS)	DC (AMP)	Peak, Recurrent (AMP)	Surge for a "turn-on" transient = 2 milliseconds (AMP)	Operating (°C)	Storage (°C)		Peak Inverse Volts = 400	Peak Inverse Volts = 500	Peak Inverse Volts = 400	Peak Inverse Volts = 500
1N1763	400	140	0.5	5	35	100	−65 to +150	3	100	—	1	—
1N1764	500	175	0.5	5	35	100	−65 to +150	3	—	100	—	1

...immediately available from your local

RCA SEMICONDUCTOR DISTRIBUTOR!

QUALITY is the reason designers of high-reliability equipment specify RCA Silicon Rectifiers. **FAST SERVICE** is the reason they order through their local RCA SEMICONDUCTOR DISTRIBUTOR.

All RCA Silicon Rectifiers are Welded and Hermetically Sealed. Entertainment types are subjected to rigid quality control procedures to provide top quality and performance. In addition, RCA types for Industrial Power Supplies and Magnetic Amplifiers undergo these extensive tests to assure reliability and long life.

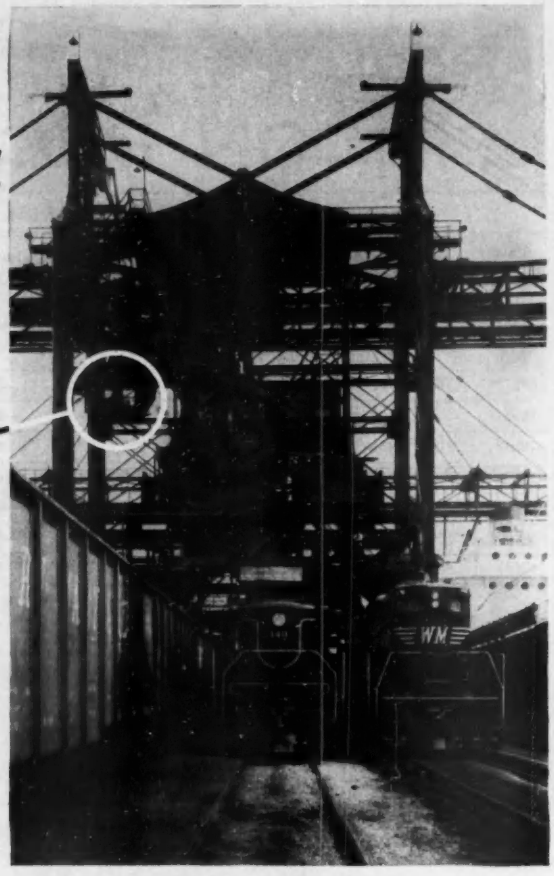
- **100% high-temperature dynamic test at full load current and rated voltage**
- **100% reverse leakage current test**
- **100% forward characteristic test**
- **100% pressure-seal test**
- **100% temperature cycling test**

So, whatever your requirements for Silicon Rectifiers—or transistors—for *fast service* check with your local RCA SEMICONDUCTOR DISTRIBUTOR. For quality products, specify RCA. *You benefit from this combination!*

RADIO CORPORATION OF AMERICA

Semiconductor Products—Distributor Sales • Harrison, New Jersey

Automation from crane to customer's office at the Western Maryland



After unloading ore from ship to railroad car, weighman in crane transmits data to yard office for automatic preparation of waybill and other documents.

Teletype Printer in a crane automates ore waybilling

As ore is transferred from ships to railroad cars at Western Maryland's Port Covington docks, a weighman high up in the control cabin of the ore-unloading crane records the lot number, tonnage, and car data on a Teletype Printer. Instantly, this information is reproduced in the yard office in punched tape—starting the automatic writing of waybills by a combination of Teletype page and tape equipment.

The only manual intervention following the transmission of the variable data from the crane is the association of fixed-data tapes by the yard clerk. The entire procedure takes just minutes—so that when the last car is coupled to the train, all waybills, arrival notices, and consignees' copies are ready. Accuracy is improved, too—since mechanization eliminates recopying errors.

As a by-product of waybill preparation, a master tape is punched automatically, which is used to produce a complete shipping statement. The system also enables the Western Maryland to give customers an extra service to speed their own accounting procedures: advance direct wire transmission of shipping statement data by Teletype equipment or a duplicate of the master tape by mail.

This installation is just one example of how railroads today are using Teletype equipment in new, imaginative ways to trim costs, improve service. This unusual application is made practical by the ruggedness built into Teletype equipment, so that it functions dependably and economically even in the dust-generating environment of ore-loading operations. If you would like information on the new Teletype Model 28 Line, please write to: Teletype Corporation, Dept. 22L, 4100 Fullerton Avenue, Chicago 39, Illinois.

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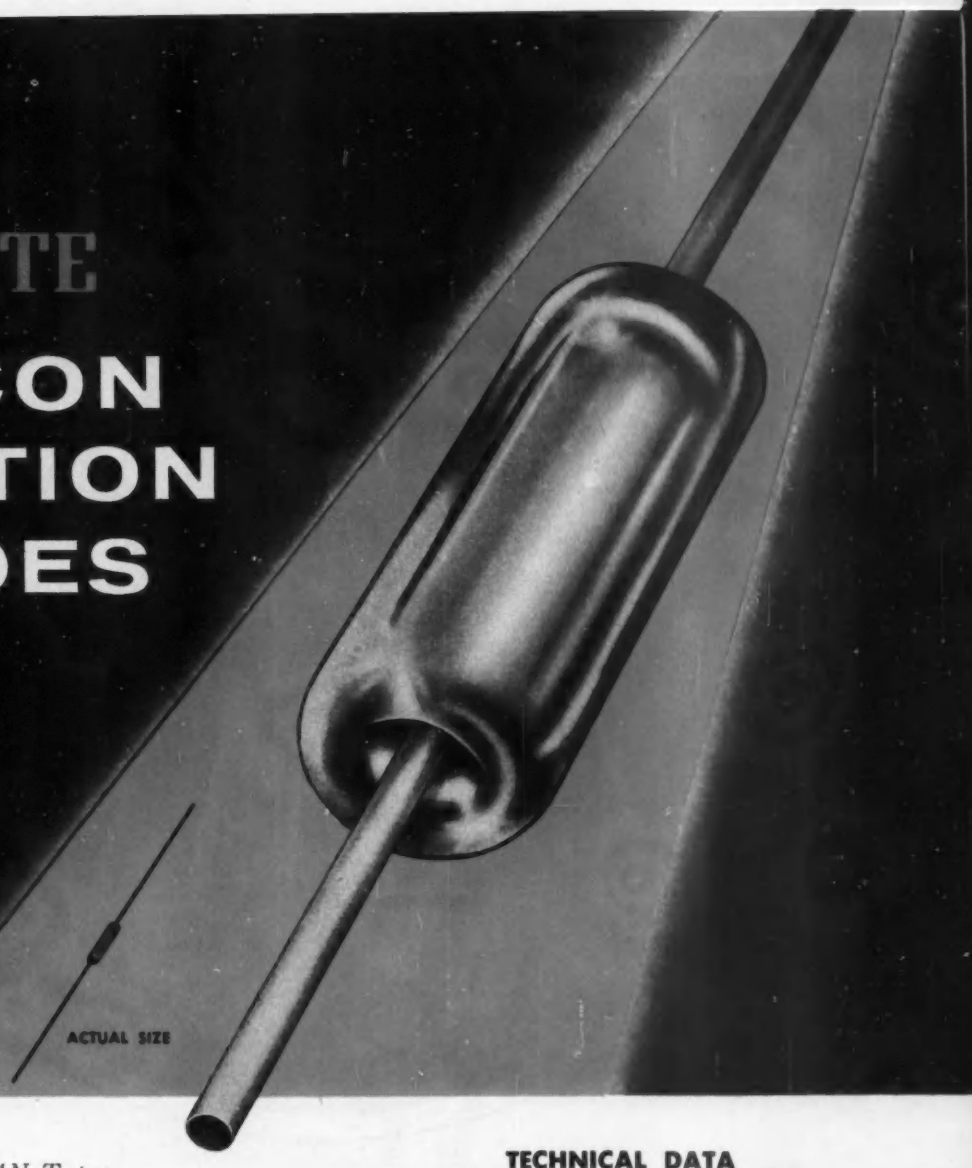
SILICON JUNCTION DIODES



250 MW Package . . .
Fast Switching and JAN Types
Featuring . . .

- **MECHANICAL RELIABILITY —— Rugged, hermetically sealed, subminiature packages. Designed to meet both military and commercial requirements.**
- **ELECTRICAL SUPERIORITY —— Excellent high temperature operation . . . thermally stable . . . high forward conductance . . . efficient rectification.**
- **JAN TYPES—IN457, IN458 and IN459 conform to JAN Specifications**

For details, write for Bulletin B217A-1 B217A-2

TECHNICAL DATA

Type	Max. DC Inver. Oper. Voltage	Forward Current @ Specified Voltage	Max. Inverse Current @ 25°C	Max. Inverse Current @ 150°C	Test Volts
IN457	60 V	20 ma @ 1.0 V	0.025 μa	5.0 μa	60 V
1N458	125 V	7 ma @ 1.0 V	0.025 μa	5.0 μa	125 V
1N459	175 V	3 ma @ 1.0 V	0.025 μa	5.0 μa	175 V
1N662	90 V	10 ma @ 1.0 V	20 μa	100 μa (@ 100° C)	50 V
1N663	90 V	100 ma @ 1.0 V	5.0 μa	50 μa (@ 100° C)	75 V
1N778	100 V	10 ma @ 1.0 V	0.5 μa	30 μa (@ 125° C)	100 V
1N779	175 V	10 ma @ 1.0 V	0.5 μa	30 μa (@ 125° C)	175 V

OTHER CLEVITE DIVISIONS:

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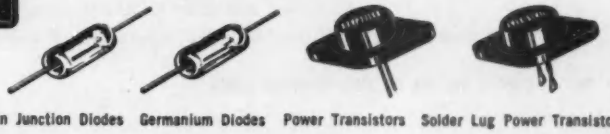

Silicon Junction Diodes Germanium Diodes Power Transistors Solder Lug Power Transistors

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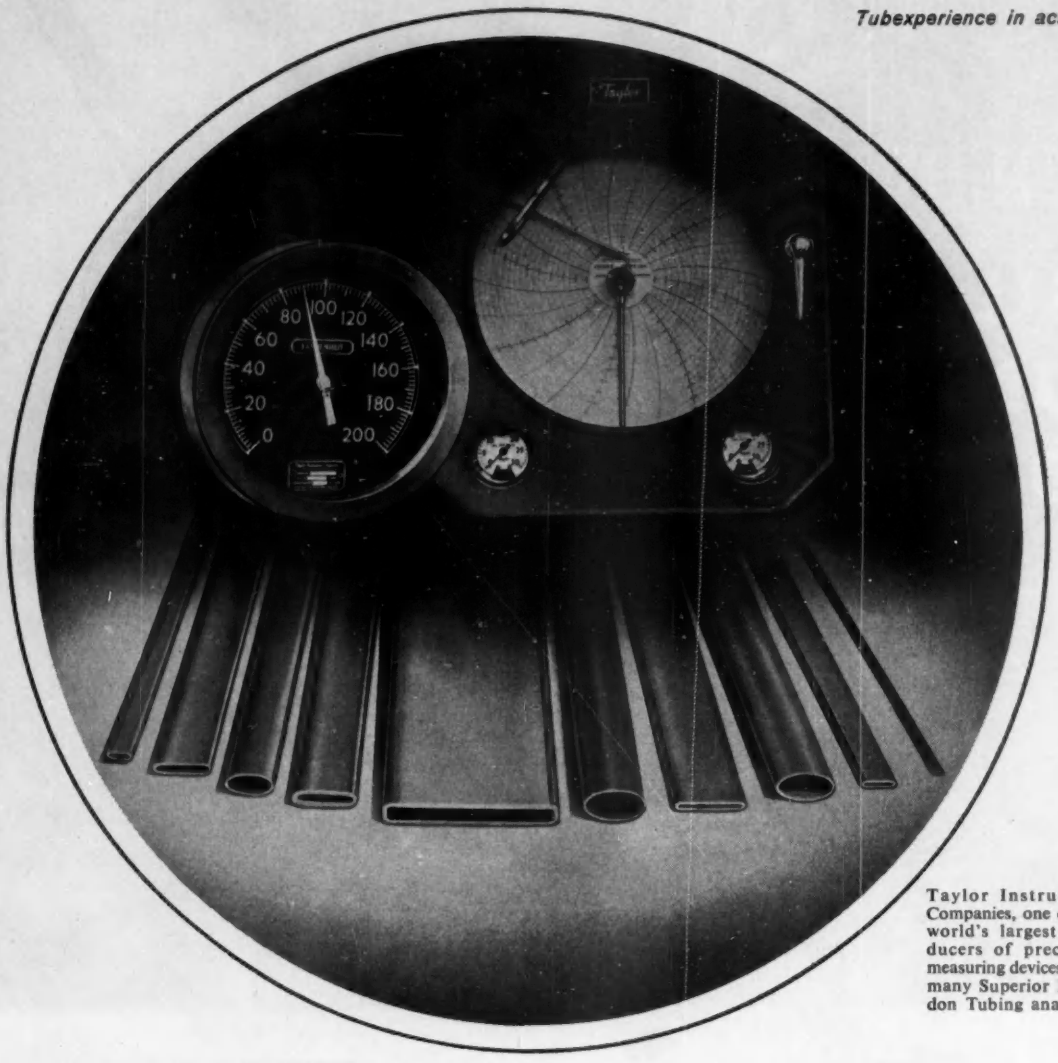
CIRCLE 77 ON READER SERVICE CARD



Taylor Instrument Companies, one of the world's largest producers of precision measuring devices, uses many Superior Bourdon Tubing analyses.

℞ for accurate indication of pressure and temperature: Bourdon Tubing by Superior

Bourdon tubes with consistent spring rate and minimum set, drift and hysteresis are essential to precision measurement of pressure in modern indicating, recording and controlling instruments. The tubing from which they are made must be free of inclusions and seams, carburization or decarburization, rough or corroded surfaces, and variations in wall thickness. Superior Bourdon Tubing has the extra qualities that permit interchangeability of Bourdon elements in the field with maximum ease, simplify range changes, require only linkage adjustment.

Typical of the care exercised in the manufacture of Superior Bourdon Tubing is the use of weight control to check tubing dimensions. This fast, precision method of checking average wall or ID enables us to provide tubing with unusually high overall uniformity. No matter how many Bourdon elements you make from Superior tubing, you get a uniform deflection rate in every case.

Superior offers a wide range of analyses, including strain-hardened, precipitation-hardened and heat-treatable materials for the fabrication of Bourdon Tube elements. Write for a copy of Bulletin 41, giving detailed information. Write Superior Tube Company, 2026 Germantown Ave., Norristown, Pa.

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅜ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

SPECIFY SPERRY

SILICON SEMICONDUCTOR DEVICES ...IN VOLUME PRODUCTION

For those applications where reliability and high performance come first, specify Sperry silicon semiconductors—now available in volume production for *your* application. Performance-proved in many exacting systems—both military and commercial—these outstanding silicon devices are ideal for stringent requirements in missile, airborne, computer and industrial applications.

Developed for maximum reliability, Sperry semiconductors are produced with extreme care in advanced manufacturing facilities under constant quality control surveillance. For the highest quality silicon devices—transistors, diodes, and rectifiers—

SPECIFY SPERRY

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SPERRY SEMICONDUCTOR DIVISION, *SPERRY RAND CORPORATION, SOUTH NORWALK, CONNECTICUT*
Sales Offices: Baltimore, Boston, Brooklyn, Chicago, Cleveland, Los Angeles, New Orleans, Philadelphia, San Francisco, Seattle

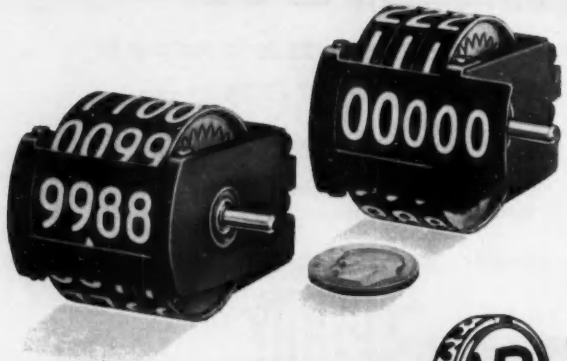
Men who Count KNOW

it pays to give their customers Veeder-Root Counting Precision

If you need ultra-precision counters to build into your product as an added service to your customers, then take a long look at Veeder-Root Instrument-type Counters, like those shown below. You'll see craftsmanship that measures up to ultra-precision standards. And you can count on it that Veeder-Root precision remains a constant quantity under highest speeds and toughest operating conditions.

Veeder-Root can bring to your counting problem the longest experience in precision counter-making of anyone in this business. Give your customers the advantages of built-in counters, give them the lifetime assurance of Veeder-Root precision.

You always "Know the score" when you count on Veeder-Root!



NEW VEEDER-ROOT MINIATURIZED COUNTERS

These Internal Pinion Counters have ⅞" wheels on which the figures are a full ¼" high, combining minimum size with maximum readability. Runs at continuous speeds of 400 rpm, and intermittent speeds of 750 rpm. Torque 1.5 oz. Meets military specifications. Originally built-in parts of navigational instrumentation, these counters are applicable to many other uses.

Everyone can Count on

Veeder-Root INC.

Hartford 2, Connecticut

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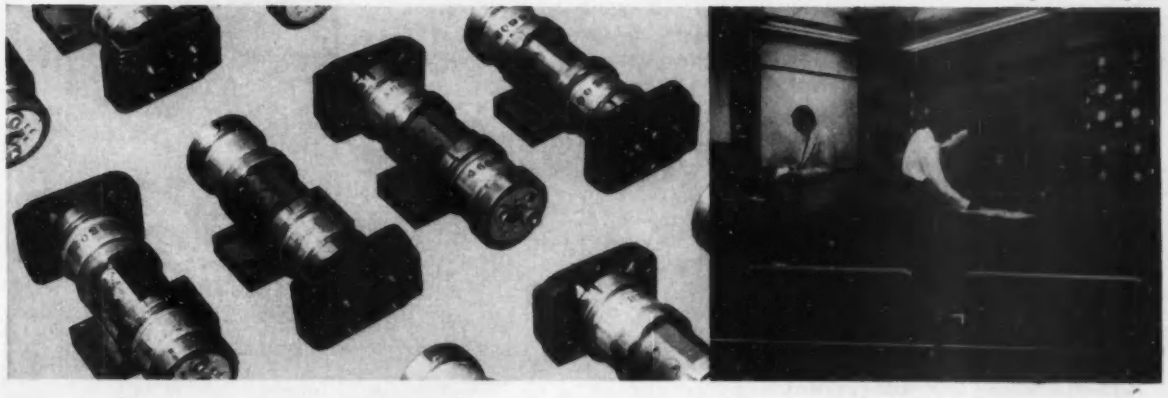
Electro-hydraulic servo system computer analysis



Here is your best source for electro-hydraulic servo valves.
Bendix-Pacific has accumulated unequalled design . . . manufacturing . . . testing . . .
and service experience in producing more than 70,000
electro-hydraulic servo valves of single and two-stage design.
If you have a servo valve problem, why not
take advantage of this tremendous backlog of experience.
BENDIX-PACIFIC is ready to put it all at your disposal.

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DIVISION OF BENDIX AVIATION CORPORATION
NORTH HOLLYWOOD, CALIFORNIA

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CIRCLE 81 ON READER SERVICE CARD 81

JOURNAL OF APPLIED CONTROL DEVICES THAT NEVER WEAR OUT

For Control Engineers Who Are Wearing Out Before Their Time

THEY TOOK ADVANTAGE OF (NO MAINTENANCE) STATIC CONTROL

Cutler-Hammer, Inc. and Arthur G. McKee & Co., American experts at control system and steel mill design, respectively, have just paid due respect to the problem of servicing complex automatic equipment in a foreign land thousands of miles away. They have installed CONTROL Switching Reactors and Transductors in the blast furnace automatic charging control designed for an Argentine steel company. Why? Because under normal operation, CONTROL Switching Reactors simply don't wear out! Yet look what they do: (1) They sequentially count charges and other functions and register this information on the operator's control panel; (2) through logic switching, they control and interlock the static skip hoist drive, the blast furnace large and small bell actuators, the automatic coke charging system, and the alarm system . . . tying them all into the operational cycle of the blast furnace. *This is static control, so named because Switching Reactors have no moving parts. Totally enclosed, these high permeability magnetic devices operate in the gritty, corrosive atmosphere of the steel mill with never a shutdown for maintenance. Want details? Write us.*

THREE LITTLE WORDS–*logic, switch, operate*

If you want some insight into Cutler-Hammer's insight, there are three words (above) to pay special attention to. *Logic:* CONTROL's Switching Reactors are designed to take a variety of input signals to be fed into several isolated control windings and thus provide AND, OR, NOT, MEMORY and TIME DELAY sequences. *Switch:* Orthonol® cores provide stiff snap action going from "off" to "on" states. The power switching ratio is 2500:1, even under 10% over-voltage conditions. *Operate:* There's no need for auxiliary hardware. CONTROL reactors directly operate such loads as solenoids, motor contactors and magnetic clutches. They're ideal for the solid state thyratron. They handle single loads up to 300VA. *We have an engineering bulletin, giving full details on the* CONTROL *reactor which drives the solid state thyratron. Write for a copy.*

STATIC CONTROL: *simple and standard*

From where do your signal pulses come? Limit switches? Push buttons? Relays? Any transducer with an electrical output? The CONTROL Switching Reactor compiles them, remembers them, and then acts (logically) when the right one comes along. It's a selective device, for by presetting it, you will insure its operating only upon the proper combination of signals. The result? A CONTROL Switching Reactor will replace a relay system, and once replaced, you minimize maintenance and other old-fashioned worries. *And there's a size for every need up to 300VA output. There are* CONTROL *reactors which operate from standard line voltages, others which deliver standard load voltages, and now there's one which takes 120 volts in and gives 120 volts out! Full details? Your copy of our catalog awaits your request.*

CONTROL Switching Reactors in Cutler-Hammer system

Reliability begins with CONTROL

A DIVISION OF MAGNETICS, INC

DEPT. CE-77 BUTLER, PENNSYLVANIA

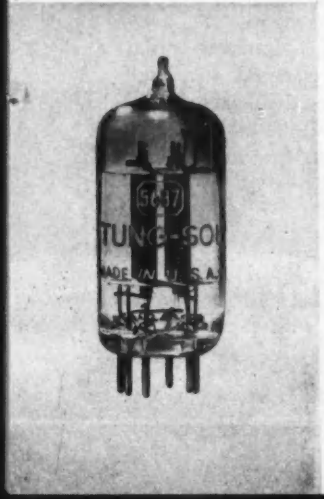
Programmer makes operational check from "driver's seat" of IBM 709 Data Processing System — the most up-to-date system utilizing electron tubes.

Tung-Sol 5687 contributes to the prime reliability of the IBM® 709 Data Processing System!

The IBM 709 Data Processing system counts on unfaltering dependability from over 500 Tung-Sol 5687 Twin Triodes — approximately 340 5687's are found in the Arithmetic and Logic unit; the remainder in the Magnetic Drum Storage unit.

Because the Tung-Sol 5687 offers excellent power handling ability, the IBM 709 employs it largely in power follower circuits to supply high current requirements . . . in driving lines with high capacity loading. Frequent 200 millimicrosecond pulses make the latter a key job in the 709. Other special-circuit uses of the 5687 include: master oscillator, pulse shaping inverters, magnetic drum write head drivers, relay drivers and single-shot multivibrators.

5687 performance points up the reliability you'll find characterizes Tung-Sol tubes and semiconductors. It gives designers in-use testimony that lets them specify Tung-Sol for critical sockets with complete assurance of full-life trustworthiness. For full technical information on the Tung-Sol 5687, or other Tung-Sol tubes or semiconductors, contact: Tung-Sol Electric Inc., Newark 4, New Jersey. TWX: NK193



ts TUNG-SOL®

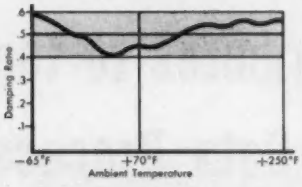
CIRCLE 83 ON READER SERVICE CARD

New Miniature Rate Gyro

Honeywell Miniature Rate Gyro
Type M-100
shown actual size

- Full Scale Range: To 400 degrees/sec.
- Linearity: Less than 0.1% of full scale to ½ range, less than 2% to full range
- Shock and Linear Acceleration: to 150G
- Size: 1" diameter, 2 19/32" long
- Threshold-Resolution: Less than 0.01 degrees/sec.
- Damping: 0.4 to 0.6 from −65°F to +250°F
- Vibration: 20 G to 2000 cps
- Weight: Less than 6.0 ounces

WARM-UP TIME
after motor run-up . . . ZERO!



When the chips are down and immediate action is a must, the new Honeywell Miniature Rate Gyros, Type M-100, are always ready. The typical damping of 0.6 at −65°F is obtained *without benefit of heat* from the spin motor, and is held virtually constant up to a temperature of +250°F. The gyro spin motor, requiring only 15 seconds run-up time, will operate on one (split), two, or three phase power, and is isolated from ground.

Other features of the Type M-100 include: unique quadrilever spring construction to produce greater shock and vibration capabilities than a comparable torsion bar gyro; elimination of one gimbal bearing for lower threshold; maintenance of preload throughout severe environmental conditions through exclusive spin motor construction.

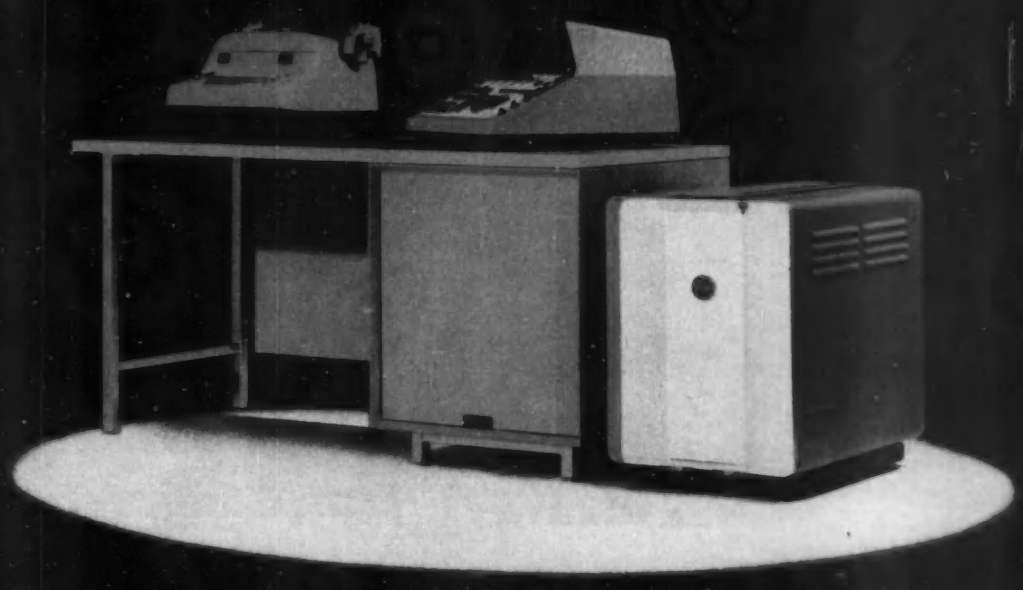
Type M-100 is specifically designed for autopilot damping, radar antenna stabilization, and fire control applications. Its small size, high performance, and ruggedness suit it particularly for advanced military aircraft and guided missile applications. Write for Bulletin M-100 to Minneapolis-Honeywell, Boston Division, 40 Life Street, Boston 35, Mass.

Honeywell

H Military Products Group

A MASTERPIECE OF FUNCTIONAL DESIGN

RECOMP



COMPACT...VERSATILE...EASY TO OPERATE

The RECOMP computer strikingly demonstrates the four basic principles of design excellence: performance, ease of operation, ease of maintenance, functional styling. It is a masterpiece of practical design.

The magnetic disk memory contains 4096 words, each of 40-bit length, or 12 decimal digits, eight alpha characters, or two program instructions. It retains as many as 8000 instructions or stores more than 49,000 decimal digits of data. Reading speed of the photoelectric tape is 400 characters a second. The exclusive digital readout flashes arabic numerals to reveal contents of any word or register.

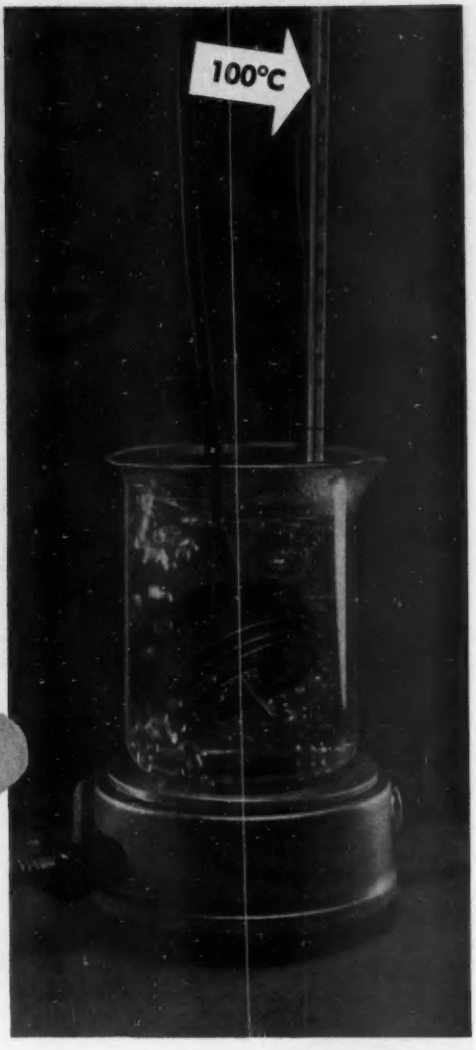
RECOMP gives you far more capacity, versatility, and trouble-free service for your money. It's available now—for outright sale or at a moderate monthly rental that includes maintenance. *And there's no extra equipment to buy...no cost of installation.* For information on how RECOMP can solve *your* problems, write Autonetics Industrial Products, Dept. 311, 3584 Wilshire Boulevard, Los Angeles 5, California.

Digital computers by Autonetics

A DIVISION OF NORTH AMERICAN AVIATION, INC.

INDUSTRIAL PRODUCTS
Other Offices: New York, Chicago, Washington, D.C.

ASCOP
ALL-MAGNETIC SHAFT-POSITION DIGITAL ENCODER



Operates Perfectly Under Boiling Water For One Week

Just to make it hard for ourselves, we boiled one of our shaft encoders for a week with its cover off. It worked fine both during and after the test. We weren't surprised. ASCOP shaft encoders use no active circuitry, no optical or mechanical contacts in readout. The only contacting parts are the stainless steel bearings. The ASCOP encoder is made for tough environments in all combinations. If you like, you can drag it through the water, shoot it to any altitude, pressure cook it, or bury it in the Antarctic and expect it to behave perfectly. We've effectively done all these things in our own environmental laboratory and we haven't yet extended an EPD-8G encoder to its limit. Try it yourself. We can make immediate delivery from stock.

Condensed Specifications

Resolution:	2^8
Operating Temperature Range:	−80°C to +100°C
Size:	2¼" dia. x 1¼"
Weight:	8 oz.
Code:	Gray
Inertia:	70 gm-cm²
Shock:	100G for 6 ms, 4 directions for a total of 12
Vibration:	55 cps to 2000 cps for 40 min. at 15G, and 10 cps to 55 cps for 20 min. at 0.12" amplitude

Brochure, price and applications notes on request . . .

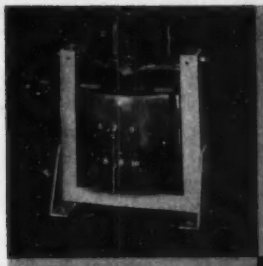
ASCOP A DIVISION OF ELECTRO-MECHANICAL RESEARCH, INC.

P.O. BOX 44 PRINCETON, NEW JERSEY

VICKERS®

designers and manufacturers of electrical products and systems for AUTOMATIC CONTROL

AUTOMATIC CONTROL PRODUCTS



MAGNETIC AMPLIFIERS

"super power", high performance, high power, special purpose (servo, low level, bi-stable, multi-stage and educational) in a complete range of sizes and voltage ratings.

Series 1000 Bulletins.

SELENIUM RECTIFIERS

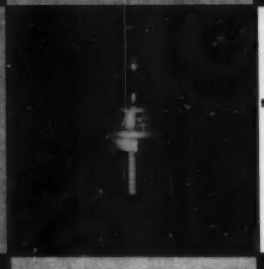
grain-oriented (T. M.) for greater rectifying efficiency, lower cost per watt. Cell ratings from 18 to 36 volts. Microamperes to 1000 amperes.

Series 3100 Bulletins.

SILICON POWER RECTIFIERS

2, 8 and 12 ampere sizes. Excellent operating characteristics, uniform quality, greater economy.

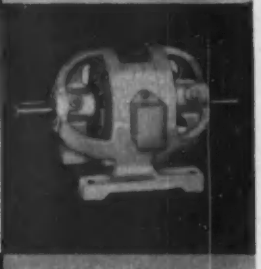
Series 3300 Bulletins.

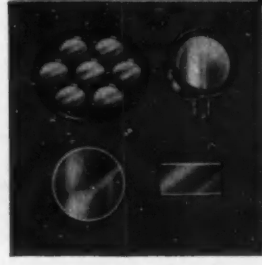


MAGNECLUTCHES® and MAGNEBRAKES®

magnetic particle clutches and brakes. Smooth, flexible operation, fast response, torque independent of speed, long life

Series 6000 Bulletins.

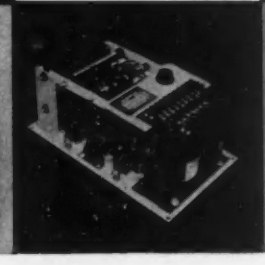




PHOTOELECTRIC CELLS

self-generating, barrier layer type, mounted or unmounted. A wide range of sizes and shapes for standard or special applications.

Series 3200 Bulletins.



REGULATORS and POWER SUPPLIES

for industrial and military applications.

Series 2000 and 9000 Bulletins.

AUTOMATIC CONTROL SYSTEMS

POSITION
SPEED
VOLTAGE
FREQUENCY
CURRENT
PHASE
PRESSURE
TEMPERATURE

Vickers' complete facilities and more than 1,000,000 man-hours of direct experience in design and manufacture of automatic control products and systems are available to assist you with your automatic control problems. Contact the sales offices below, or write direct to us.

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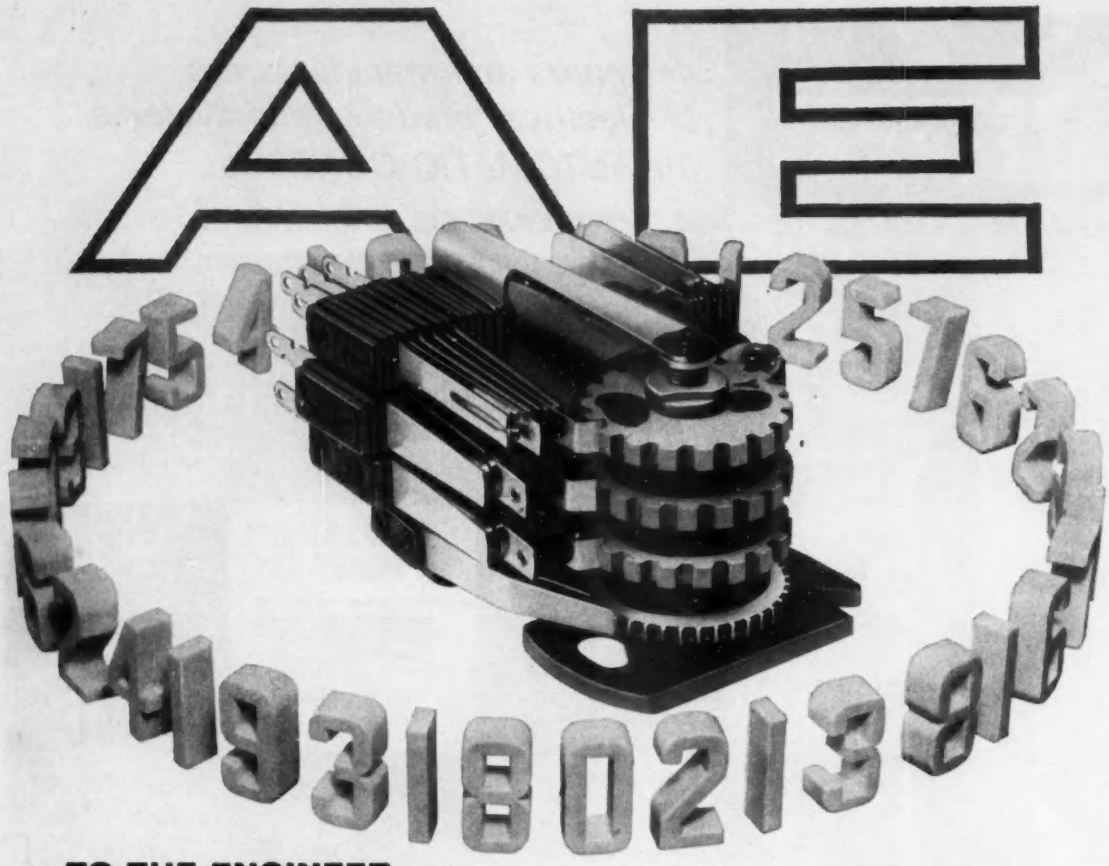
CIRCLE 87 ON READER SERVICE CARD 87



TO THE ENGINEER

who can't tolerate a lapse of memory

If you're working on a think machine that can't afford to break its train of thought, consider AE's pint-size, fast-stepping OCS switcher. Unlike electron tubes and relays, this sophisticated device won't lose stored memory in the event of power failure or circuit interruption.

Besides, it can do the work normally assigned to whole banks of relays.

The AE Series OCS will follow or initiate a prescribed series of events or cycles at 30 steps per second impulse-controlled, or 65 steps per second self-interrupted. Any programming sequence can be set up on one to six cams with as many as 36 on-and-off steps per cam. And each cam will actuate as many as six contact springs.

In any event, if your designs involve relays or stepping switches, AE circuit engineers may be able to save you a pretty penny. Or, if you'd like to leave the switching to us, we're equipped to supply prewired and assembled, custom-built control units, *or* help you develop complete control systems.

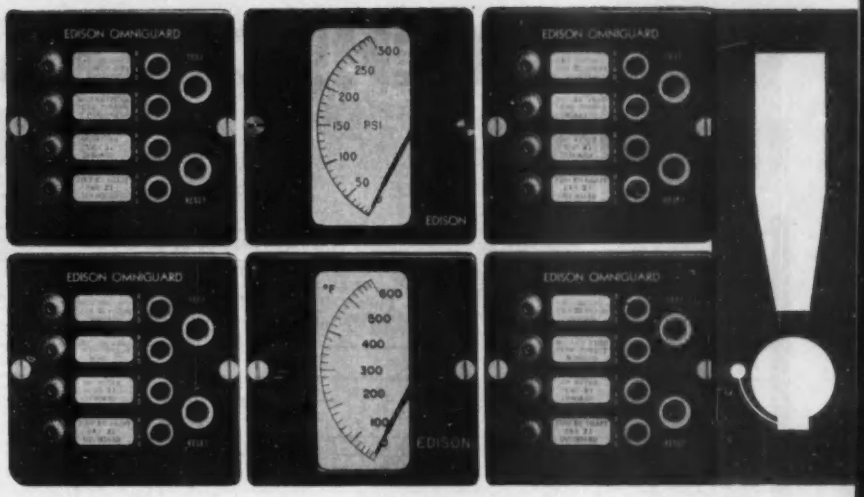
To explore the matter, just write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. Also ask for Circular 1698-H: *Rotary Stepping Switches;* Circular 1702-E: *Relays for Industry;* and our new 32-page booklet on *Basic Circuits.*

AUTOMATIC ELECTRIC GENERAL SYSTEM

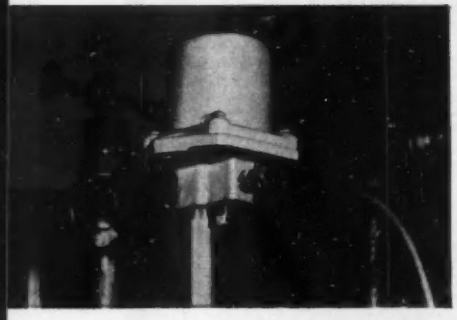
Subsidiary of

GENERAL TELEPHONE & ELECTRONICS

GUARD ALL CRITICAL PRESSURES AND TEMPERATURES WITH THOMAS A. EDISON LOW-COST, OMNIGUARD WARNING SYSTEM



Here is a versatile, highly-reliable continuous warning and monitoring system. By simply pushing a button on this panel you obtain a reading of *key pressure* and *temperature* points throughout your plant. In addition, this system provides instantaneous warning when pressure or temperature deviates from pre-set limits.

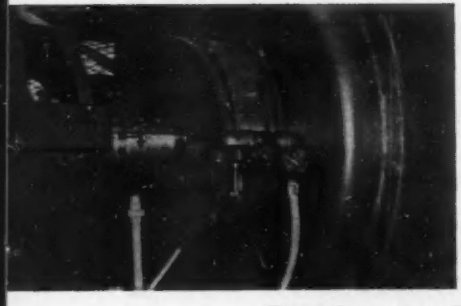


Compact, reliable Resistance Pressure Detector transmits changes in pressure to central control panel.

PRESSURE

With the Edison Omniguard system you can monitor gas, fluid or vapor pressure. Heart of the system is a rugged, accurate, pressure detector which converts pressure directly to electrical resistance—requires no millivolt conversion—no amplifier. For pressures under 60 PSI a precision capsule is the sensing element. From 60 to 3000 PSI special bourdon tube elements are used.

When pressure changes, resistance varies and this deviation is transmitted to the control panel. Units operate over ambient temperatures of 32° to 150°F. Control panels are available with a wide variety of scales and are equipped with both normally open and normally closed alarm contacts to operate any type of auxiliary device or to automatically shut down machinery or process.



Rugged, accurate Resistance Temperature Detector guards against overheating of this motor bearing.

TEMPERATURE

Edison Omniguard also provides reliable protection from overheating. You can monitor the temperature of bearings, gases and liquids in critical equipments or processes. Reliable Edison Resistance Temperature Detectors have no moving parts and give instantaneous warning when limits are exceeded. Unlike other systems which only scan, Omniguard is continuously monitoring. You can obtain exact readings of temperatures in all parts of your plant from one central control panel.

For greater flexibility and reliability each detector circuit is completely independent. If one circuit is damaged, all other circuits remain "on guard." When changes or additions are required they can be accomplished quickly and easily.

Thomas A. Edison Industries
INSTRUMENT DIVISION
38 LAKESIDE AVENUE, WEST ORANGE, N. J.

CIRCLE 89 ON READER SERVICE CARD

WHICH BENDIX TRANSISTOR IS BEST FOR THE JOB?

TYPICAL OPERATION AND MAXIMUM RATINGS OF BENDIX GERMANIUM PNP TRANSISTORS

Type Number	PRIMARY APPLICATIONS				MAXIMUM RATINGS				TYPICAL OPERATION			
	Audio	Push-Pull	Switch	Power Supply	Collector Voltage Vce (a)	Collector Current Ic	Thermal Resistance (b)	Junction Temp. Tj	Current Gain hFE —	Current Gain Ic Adc	Circuit Gain db	Power Output W
High Power Transistors (g)												
2N155	X				30 Vcb	3 Adc	3° C/W	85°C	40 (c)	0.5	33	2
2N176	X				40 Vcb	3	—	90	45 (c)	0.5	35	2
2N234A	X				30	3	2	90	25 (c)	0.5	30	2
2N235A, B	X				40	3	2	90	40, 60 (c)	0.5	33, 36	2
2N236A, B	X			X	40	3	2	95	40, 60 (c)	0.75	33, 36	4
2N242	X				45 Vcb	2	3	100	—	—	35	1
2N255	X	X			15 Vcb	3	3	85	40	0.5	22	1
2N256	X	X			30 Vcb	3	3	85	40	0.5	25	2
2N257	X				40	—	—	85	55 (c)	0.5	35	1
2N268, A	X		X		80 Vcb	—	—	85, 90	—, 40	—, 2.0	31, —	1, —
2N285A	X			X	40	3	2	95	150 (c)	0.5	40	2
2N297			X		60 Vcb	5	2	95	70	0.5	—	50 (d)
2N301, A	X				40, 60 Vcb	3	—	—	63 (c)	0.7	33	3
2N307, A	X				35 Vcb	1, 2	5, 3	75	80	0.2	—, 27	—, 1
2N399	X	X			40	3	2	90	40 (c)	0.75	33	8 (e)
2N400	X			X	40	3	2	95	50 (c)	1.0	36	6
2N401	X	X			40	3	2	90	40 (c)	0.5	30	5 (e)
2N418			X	X	80	5	2	100	50	4.0	—	100 (d)
2N419				X	45	3	2	95	60 (c)	0.5	—	5
2N420, A			X	X	40, 70	5	2	100	50	4.0	—	—
2N637, A, B	X		X	X	40, 70, 80	5	2	100	45	3.0	—	35, 70 (d)
2N638, A, B	X		X	X	40, 70, 80	5	2	100	30	3.0	—	35, 70 (d)
2N639, A, B	X		X	X	40, 70, 80	5	2	100	23	3.0	—	35, 70 (d)
2N677, A, B, C and 2N1029, A, B, C replaced by 2N1031, A, B, C												
2N678, A, B, C and 2N1030, A, B, C replaced by 2N1032, A, B, C												
2N1031, A, B, C	X		X	X	30, 40, 70, 80	15	1.5	100	40	10.0	—	75, 125, 250 (d)
2N1032, A, B, C	X		X	X	30, 40, 70, 80	15	1.5	100	75	10.0	—	75, 125, 250 (d)
2N1073, A, B (i)	X		X		40, 80, 120	10	2.0	100	40	5.0	—	100, 150, 200 (d)
2N1136, A, B	X		X	X	40, 70, 80	5	2.0	100	75	3.0	—	35, 70 (d)
2N1137, A, B	X		X	X	40, 70, 80	5	2.0	100	115	3.0	—	35, 70 (d)
2N1138, A, B	X		X	X	40, 70, 80	5	2.0	100	150	3.0	—	35, 70 (d)
B-177	X			X	30	3	2.2	90	150 (c)	0.5	39	2
B-178	X				30	3	2.2	90	40 (c)	0.5	33	2
B-179	X				40	3	2.2	90	25 (c)	0.5	28	2
Medium Power Transistors (h)												
2N1008, A, B	X	X	X		20, 40, 60	300mA	0.15°C/mW	85	95 (c)	10mA	—	400mW (f)
2N1176, A, B	X		X		20, 40, 60	300mA	0.20°C/mW	85	50 (c)	10mA	—	300mW (f)
Military Types												
2N297A (g)	X		X	X	50	5	2.0	95	70	0.5	—	35 (f)
2N331 (h)	X		X		30 Vcb	200mA	0.15°C/mW	85	50 (c)	1.0mA	—	400mW (f)
2N1011 (g)	X		X	X	70	5	2.0	95	55	3.0	—	70 (d)
2N1120 (g)	X		X	X	70	15	1.5	95	35	10.0	—	250 (d)

(a) Vce except where noted. Equivalent Vcb's are 20-50% higher. (b) Collector dissipation is the difference between the maximum junction temperature and the mounting base temperature divided by the thermal resistance. (c) hfe, AC current gain. (d) Square wave output power. (e) Push-pull output. (f) Pc—Maximum collector dissipation 25°C. (g) TO-3 package. (h) TO-9 package. (i) Diffused-Alloy-Power DAP transistor.

CHARACTERISTICS OF BENDIX SILICON RECTIFIERS

Type Number	Io Adc	PIV Vdc	Ilb	Type Number	Io Adc	PIV Vdc	Ilb	Type Number	Io Adc	PIV Vdc	Ilb
1N536	0.75	50	10 uAdc (At 25°C)	1N1434	30	50	5 mAdc (At 150°C)	1N1612	5	50	1 mAdc (At 150°C)
1N537	0.75	100	10 uAdc	1N1435	30	100	5 mAdc	1N1613	5	100	1 mAdc
1N538	0.75	200	10 uAdc	1N1436	30	200	5 mAdc	1N1614	5	200	1 mAdc
1N539	0.75	300	10 uAdc	1N1437	30	400	5 mAdc	1N1615	5	400	1 mAdc
1N540	0.75	400	10 uAdc	1N1438	30	600	5 mAdc	1N1616	5	600	1 mAdc
1N547	0.75	600	10 uAdc								

Write Semiconductor Products

Red Bank *Division*

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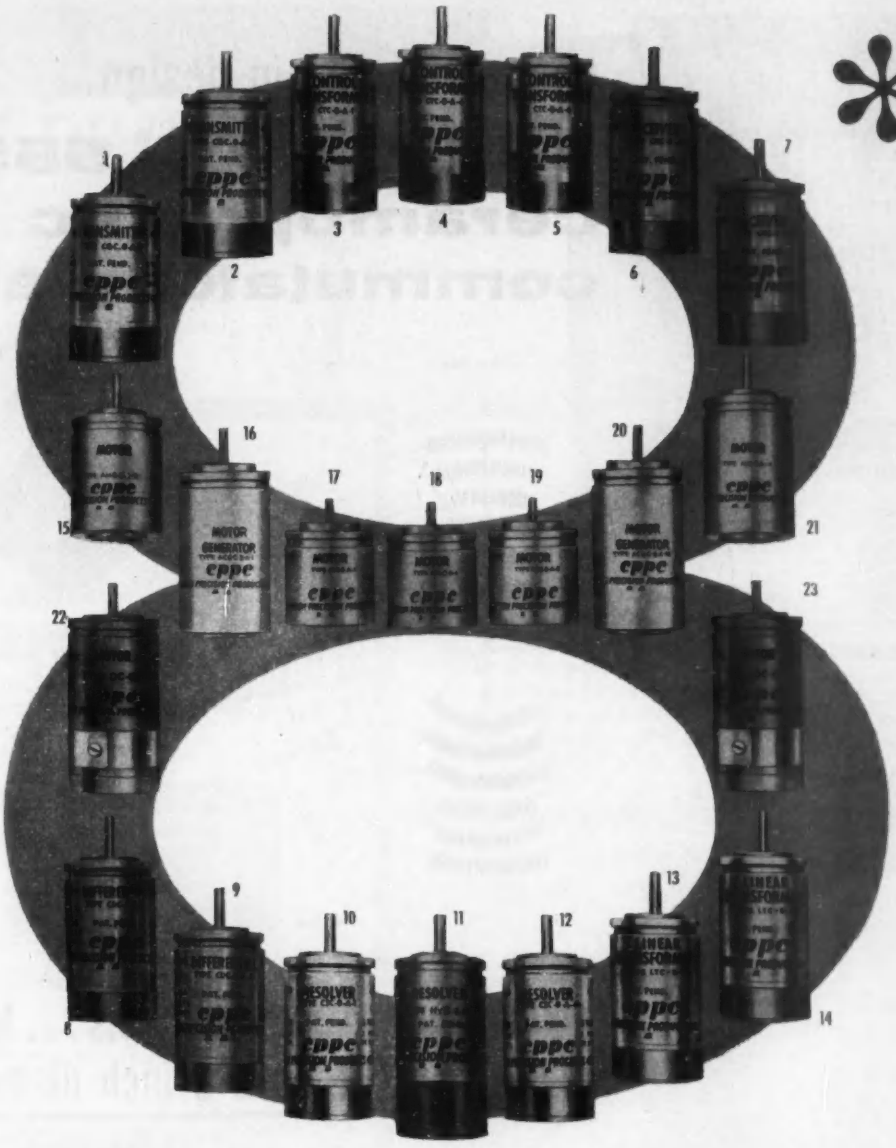
New England Sales office: 4 Lloyd Road, Tewksbury, Massachusetts • Export Sales office: Bendix International Division, 205 E. 42nd Street, New York 17, New York
Canadian Affiliate: Computing Devices of Canada, Ltd., P. O. Box 508, Ottawa 4, Ontario, Canada



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Clifton Precision's size 8 rotary components have been tried and proven by customers over the past 4 years. More than 50,000 have been shipped. These are the most accurate and best tested (because they are use tested) size 8 rotary components on the market today.

1. Torque transmitter (26v. input) 2. Torque transmitter (115v. input) 3. Control transformer (lo Z) 4. Control transformer (hi Z) 5. Control transformer (very hi Z) 6. Torque receiver (26v. input) 7. Torque receiver (115v. input) 8. Torque differential (lo Z) 9. Torque differential (hi Z) 10. Electrical resolver (.5 t.r.) 11. Precision computing resolver (feedback winding) 12. Electrical resolver (1 t.r.) 13. Linear transformer (115v. input) 14. Linear transformer (26v. input) 15. Servo motor (1" length, .40 in-oz stall torque) 16. Motor generator (10v. input) 17. Servo motor (53/64" long) 18. Servo motor (35v. center tap) 19. Servo motor (26v. center tap) 20. Motor generator (26v. input) 21. Servo motor (.30 in-oz stall torque) 22. D.C. motor (14v. input) 23. D.C. motor (28v. input)

ENGINEERS—Join the leader in the rotating components field. Write David D. Brown, Director of Personnel, Dept. N11.

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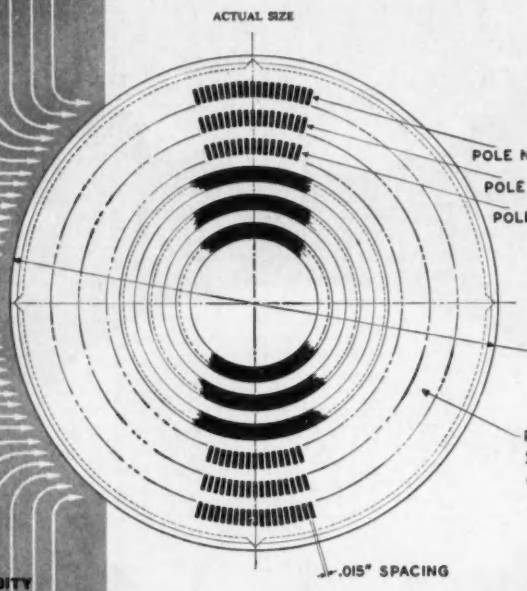

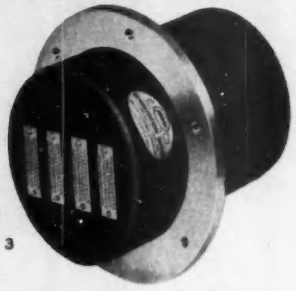

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RESISTANCE MEASUREMENT: Built with Cubic's years-ahead design and careful attention to fine detail, the Ohmmeter gives rapid, accurate measurement of resistors and resistance materials.

VOLTMETER UNIT, featuring front and rear panel input terminals and wide output capabilities for multiple applications. Models V-41, V-51.
AC CONVERTER UNIT, featuring high input impedance, extreme stability, linearity and accuracy. Models AC-1 (Manual Ranging), AC-2 (Automatic).
OHMMETER UNIT, featuring four-wire input leads, superior input filter, automatic range selection, high accuracy. Models 0-41, 0-51.
CONTROL UNIT, featuring quality-engineered DC Power Supply, Precision Reference, Amplifier. Models C-1, C-2 (without Reference for use with Ohmmeter).
SCANNER UNITS, featuring Master and Auxiliary Scanners capable of selecting up to 1000 input channels. Models MS-1, AS-1.
PRINTER CONTROL UNITS, featuring all controls necessary to integrate printers with a Digital Measuring System. Models PC-series.
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analog computers

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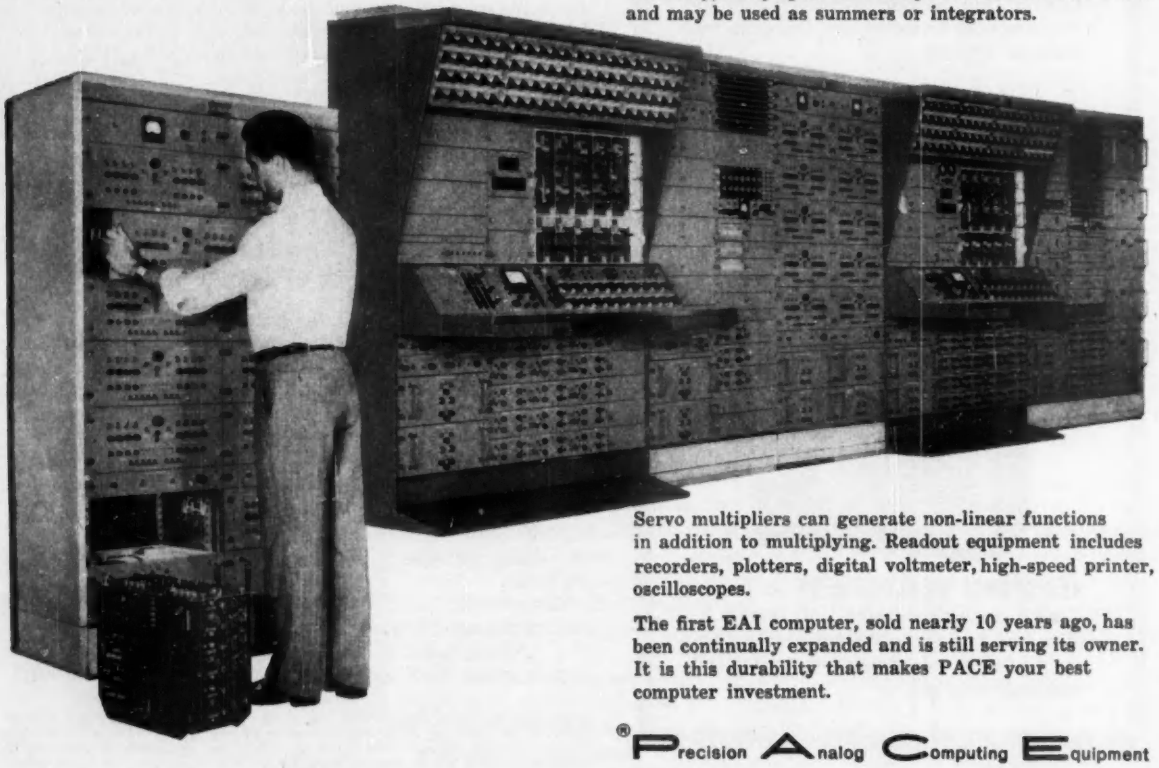
MODULAR DESIGN PROVIDES FLEXIBILITY AND ECONOMY

The PACE 231R is one of the most versatile, flexible computers ever designed. It is composed entirely of standard production line components. As a result, you have the benefit of a custom-built computer without the costs of special design.

You can start with a single console containing 40 operational amplifiers and 20 coefficient potentiometers (or less)—then expand by adding standard plug-in components, stock harnesses, and hardware. No soldering, no cable lacing, no metal work required. A single console can contain up to 80 operational amplifiers, 150 coefficient potentiometers and additional control and operational components.

Large 3450 hole pre-patch panel provides terminations for up to 100 amplifiers, 150 potentiometers, and many assorted linear and non-linear components. When your demands exceed the capacity of the basic console, components can be added in groups—housed in compact, rugged racks which blend perfectly with the basic console.

You can choose from the world's widest line of computing components and accessories. For example, EAI offers 61 different types of servo and electronic multipliers and a wide variety of fixed function generators for performing sin x, cos x, x^2, log x, x^4 and other commonly encountered mathematical operations. For added flexibility, many operational amplifiers are non-committed and may be used as summers or integrators.

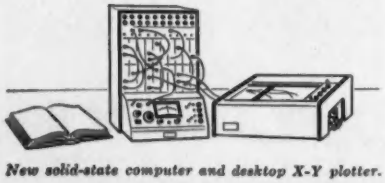


Servo multipliers can generate non-linear functions in addition to multiplying. Readout equipment includes recorders, plotters, digital voltmeter, high-speed printer, oscilloscopes.

The first EAI computer, sold nearly 10 years ago, has been continually expanded and is still serving its owner. It is this durability that makes PACE your best computer investment.

®Precision Analog Computing Equipment

Outstanding opportunities for engineers with proven ability—resumes invited.



New solid-state computer and desktop X-Y plotter.

EAI

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Long Branch, New Jersey

The Competition Is Murder In Computing-Control

Manufacturers of digital computers for on-line control predict 1960 will be a good year for them. To find out how good the year will be, CONTROL ENGINEERING surveyed the major known manufacturers of such equipment, **learned that sales next year could go as high as 99 units, almost $10,000,000 worth of computers alone—almost double 1959 sales.**

Three areas

Although the computers were originally designed for inclusion in control loops, makers are finding a good market for their machines outside the loop. Therefore CtE asked manufacturers to predict their sales in three areas: 1) computers for use in control, 2) computers for computing-logging functions, and 3) computers for on-line processing such as on-line test and data reduction, inventory control, and production control. Here's what manufacturers expect to sell—not deliver—in 1959 and 1960:

	Actual Sales to Sept 1959	1959 Total Sales	1960 Total Sales
Computing-Control	24	25	28
Computing-Logging	20	27	50
Other On-Line processing	8	10	21
Totals	52	62	99

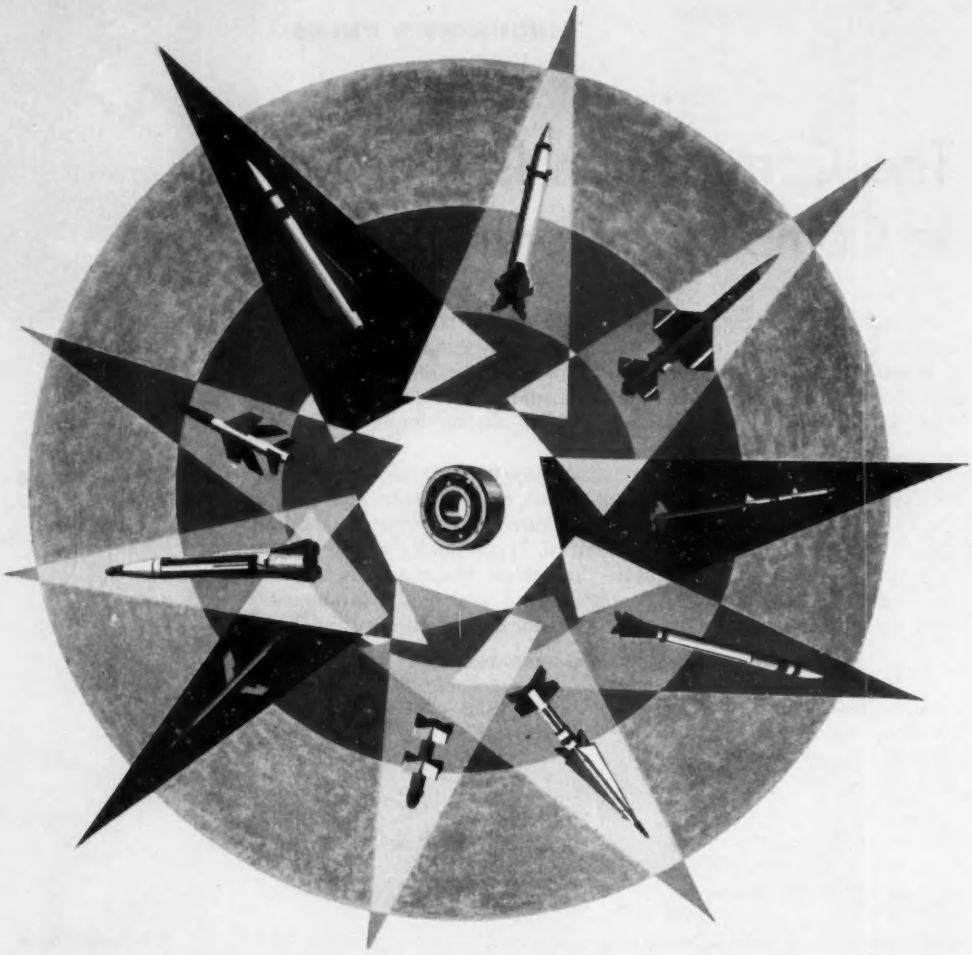
Manufacturers think that many jobs that start out as information systems, doing a computing-logging function, will finally end up in some kind of feedback control.

Competitors everywhere

Although the market is developing faster than most people expected—in CtE's September 1957 issue on Computing-Control, for example, a survey predicted only a $5 million market for 1960—manufacturers are concerned with sharply growing competition in the field. At the 1958 ISA show, only three manufacturers offered such computers for sale (Thompson-Ramo-Wooldridge Products' RW-300, Librascope's Libratrol 500 and Daystrom's Information System). By the 1959 show, the number had jumped to twelve (with the addition in the field of GE's 312, RCA's 110, Panellit's 609, L&N's 3000, Autonetics Recomp II, Genesys' DDA, Westinghouse's Opcon, Bendix's G-15, and a Ferranti machine). One manufacturer's sales manager is sure there will be at least 18 suppliers of computers for control by 1961. He was also betting that IBM, Minneapolis-Honeywell and Westinghouse Electric Corp. (with a new general purpose machine) would be the next companies to announce such devices. And he expects French manufacturer Compagnie de Bull to launch an extensive marketing program in the U.S. for a control computer.

A spokesman at Bailey Meter Co. admitted to CtE that his company was studying the digital field, would have an announcement of some kind within the next year. Bailey is still exploring the two possibilities: an arrangement with an established computer maker (along the lines of the recently announced Foxboro-RCA deal) and developing its own digital machine for control.

Spreading the estimated 99 sales among three computer manufacturers makes a bright picture; spreading the same number among 18 suppliers is not so bright. And the manufacturers already in the business predict



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U.S. Major Missile Makers Depend on ND Reliability!

In super-precision high speed gyro rotors for guidance systems . . . or in delicately precise instrumentation . . . more and more missile manufacturers are turning to New Departure for *proven reliability!*

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MINIATURE & INSTRUMENT BALL BEARINGS

proved reliability you can build around

that the new ones will be putting on the pressure to make their first sales to garner prestige as well as operational know-how.

Special Markets

To protect their positions, the established manufacturers are drawing beads on specific parts of the market, although they're interested in selling a computer to any part. TRWP, for example, is concentrating on the chemical and petroleum processing field and the missile and aircraft test business. Daystrom Systems, Inc. has channeled most of its efforts towards public utilities and petroleum processing. General Electric is giving special attention to the electric utility industry and steel plants. Leeds & Northrup aims primarily at the electric utility industry. Librascope is firing its biggest selling guns at gas utilities, pipeline companies, and steel plants.

The Buyers

To see who's buying control computers, CtE tracked down sales made to date. They show a surprising breadth:

RW-300
- Texaco, Inc.
- Monsanto Chemical Co.
- Riverside Cement Co.
- Goodrich Chemical Co.
- Sperry Engineering Laboratory
- Douglas Aircraft Co.
- Federal Aviation Agency
- French Atomic Energy Commission (2)
- Bendix Aircraft Co.
- Unannounced pilot plant
- Unannounced

Daystrom Systems
- Louisiana Power and Light (2)
- Universal Oil Products Co.
- Carolina Power & Light Co.
- Kansas City Gas & Electric Co.

Libratrol 500
- Public Service of Colorado

Royal McBee LGP-30
- Standard Oil of New Jersey
- Standard Oil of New Jersey—CEC
- Western Eletric

Bendix G-15
- Cornell Aeronautical Laboratory

GE 312
- Jones & Laughlin Steel Co.
- Southern California Edison (2)
- Unannounced steel plants (3)

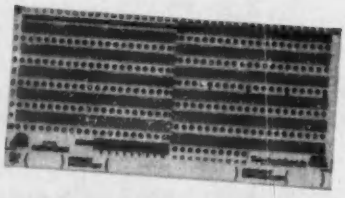
LN 3000
- Public Service of New Jersey

Panellit 609
- du Pont (3)
- Gulf States Power Co.

Recomp II
- Phillips Chemical Co.
- Standard Oil of California
- Sanders Associates
- Autometrics Div., Paramount Pictures, Inc.
- Stanford Research Institute
- U. S. Army Electronic Proving Grounds

Westinghouse OPCON
- Sun Oil Co.
- Dow Chemical Co.
- Westinghouse Capacitor Div.

Prospects are that computing-control will be making news for most of 1960. One possible new development: an airborne control computer will be repackaged for process control applications; occupying only a small space, it will be capable of being installed out-of-doors (if need be) in refinery or chemical plants or along pipelines.

Here's the secret  *of the*

Another example of Excelsior Mills leadership

Excelsior Mills manufacture quality woolen fabrics which are sold through Milliken Woolens, Inc., New York, to America's leading manufacturers of apparel for men, women and children. Excelsior Mills are noted for their efforts to seek the best production methods to assure top quality fabrics.

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Taylor Instruments

most advanced Batch Process Controller

TAYLOR ANNOUNCES THE NEW

CARD-O-TRON* PUNCH-CARD TIMER!

Punch the card for any batch process cycle—and that cycle can be repeated *exactly* at any time in the future by simply inserting that card in the CARD-O-TRON Timer. This revolutionary new CARD-O-TRON Timer eliminates the hazards of human error by making every phase of the process completely automatic. Saves repeated trial-and-error settings. Insures absolute uniformity of product. Saves operator time.

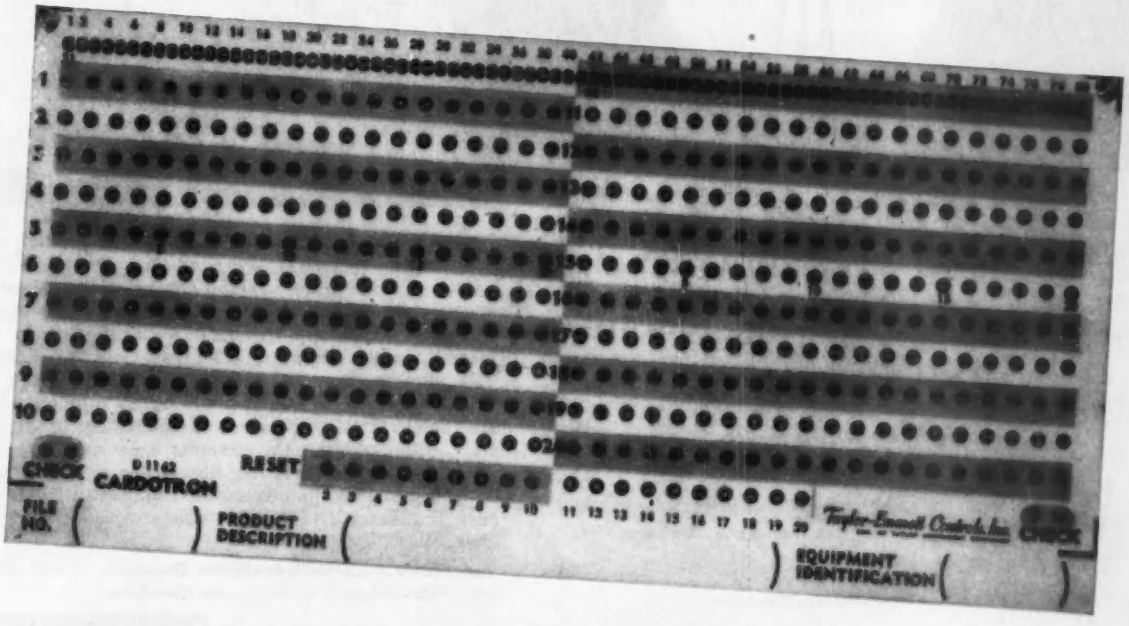
The Dolly Washer application shown here, at Excelsior Mills, Inc., Union Division, Union, S. Carolina, is one example of how the CARD-O-TRON Timer can 'automate' a process. The operator simply inserts the punched card and pushes the start button. Then the control system takes over and automatically completes the required cycle.

For instance, for one of the cycles used the timer: **1.** Starts Dolly Washer Motor. **2.** Fills Washer to predetermined level. **3.** Times and temperature-controls first rinse. **4.** Empties the Washer. **5.** Refills to predetermined level. **6.** Adds soap. **7.** Times and temperature-controls soaping cycle. **8.** Times and temperature-controls hot rinse. **9.** Times and temperature-controls cool rinse. **10.** Completes cycle and signals operator.

The CARD-O-TRON Punch-Card Timer is a product of our subsidiary, Taylor-Emmett Controls, Inc. It is sold and serviced by Taylor Instrument Companies, Rochester, New York, and Toronto, Ontario.

Call your Taylor Field Engineer to find out how you can put this remarkable new Timer to work on your batch processes.

*Trade-Mark



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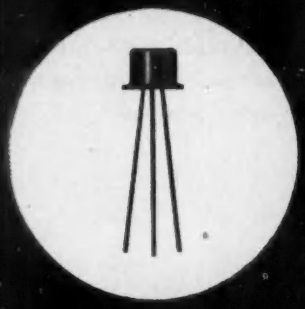
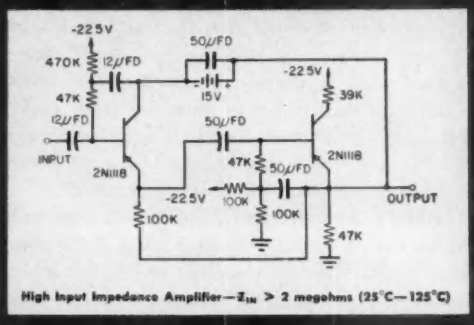
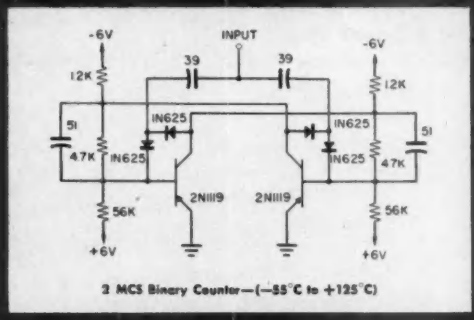
SILICON TRANSISTORS



For Proven Performance in High Speed Circuits at High Temperatures



High Input Impedance Amplifier—Z_{IN} > 2 megohms (25°C—125°C)



2 MCS Binary Counter—(−55°C to +125°C)

SAT* 2N1118 and 2N1119 offer 4 outstanding features:

1. Low Leakage Current
2. Very Low Saturation Resistance (Choppers, Switches)
3. High Base-emitter Breakdown Region
4. Controlled Input Characteristics

2N1428 and 2N1429 are Lower-priced Units with Comparable Characteristics for Low Voltage, High Beta Application.

*Trademark Philco Corp. for Surface Alloy Transistors

Philco continues its leadership in the Silicon high speed PNP field with these highly reliable field-proven SATs. In addition to their other superior characteristics, they have adequate frequency response to fill a large percentage of silicon transistor applications in both military and commercial circuits operating at high ambient temperatures. They are environmentally tested in accordance with MIL-T-19500 A. These two new types supplement and are the electrical equivalents of the widely used 2N495 and 2N496, offering the designer a choice of packages (TO-1 and TO-5). For very high speed switching applications, designers should consider Philco's NPN Diffused-base Transistor 2N1199. *Write for complete information, Dept. CE 1159.*

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TRANSISTOR CENTER U.S.A.

CIRCLE 100 ON READER SERVICE CARD

Control
ENGINEERING

NOVEMBER 1959

Gifted Students Need You

We are far removed from the frontier days when parents often had to teach the Three R's to their children. Today most of us are willing to relegate to professionals the job of educating youngsters. But we could give—and for that matter, receive—much more in the educational process if we returned a bit to the pioneers' personal approach. We could take a greater part in teaching gifted pre-college students some of the mathematical and scientific principles we use in our engineering work but which few high schools can handle. We commend the efforts of one man and some control makers who are doing just this. The man is David M. Boyd, chief instrument engineer for Universal Oil Products Co. The young men in his program attend Hinsdale High School, Illinois, during the day; at night their subject is computer technology. (See pictures on page 30.)

The boys worked for a year and a half building a computer using relays and a Flexowriter donated by Panellit, Inc. After some instruction in Boolean algebra by Mr. Boyd, the group designed and built relay circuits for addition, subtraction, shift register, and a 20-word memory. Further progress was stalled by the need for a memory with greater capacity. At this point CONTROL ENGINEERING editors and salesmen rallied to procure donations of a magnetic drum, diodes, transistors, and other components. Today the contributor scoreboard looks like this:

Panellit, Inc.: relays, Flexowriter
Friden, Inc.: rebuilding of the Flexowriter
Bryant Computer Products Div.: magnetic drum with 50 heads
Hoffman Semiconductor Div.: silicon diodes
Lansdale Tube Co. Div.: transistors
Raytheon Semiconductor Div.: transistors, diodes
Transistron Electronic Corp.: diodes
Clevite Transistor Products, Inc.: diodes
Heath Co., Div. of Daystrom, Inc.: oscilloscope kit, power supplies
Systems Div. of Daystrom, Inc.: transistors
Sun Electric Corp.: meters
International Resistance Co.: carbon resistors
Amco Engineering Co.: cabinet

Since the drum arrived ten weeks ago, the boys have assembled 100 transistorized flip-flops with which they have constructed two 32-bit shift registers, a 13-bit shift register, a synchronizing circuit, a head selector, a 6-bit shift register for Flexowriter input, and add and subtract units—all designed by themselves. Later the crew will build sub-loops for multiplication and division.

Mr. Boyd and the contributing companies feel that the enthusiasm of the boys and their gain in knowledge are sufficient rewards. CtE has enjoyed playing the part of catalyst. And all commend this sort of spontaneous education to you. It does not require a set curriculum, regular hours, or a schedule of accomplishments. It all depends on enthusiasm and personal attention to the abilities of each student. Gifted students are sure to develop the enthusiasm if you provide the attention.

W. E. Vannah

NEW MODEL 122A

AT LAST!
A Precision 200 KC Scope with Dual Trace Presentation!

Here at last is a 200 KC oscilloscope—priced at just $625—giving you "big-scope" versatility and the time-saving convenience of simultaneous two-phenomena presentation.

Engineered to speed industrial, mechanical, medical and geophysical measurements in the 200 KC range, the new hp 122A has two identical vertical amplifiers and a vertical function selector.

The amplifiers may be operated independently, differentially on all ranges, alternately on successive sweeps, or chopped at a 40 KC rate.

Other significant features include universal optimum automatic triggering, high maximum sensitivity of 10 mv/cm, 15 calibrated sweeps with vernier, sweep accuracy of ±5% and a "times-5" expansion giving maximum speed of 1 μsec/cm on the 5 μsec/cm range. Trace normally runs free, syncing automatically on 0.5 cm vertical deflection, but a knob adjustment eliminates free-run and sets trigger level as desired between −10 and +10 volts. Rack or cabinet mount; *rack mount model only 7" high.*

For complete details, write or call your hp representative, or write direct.

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FIELD REPRESENTATIVES IN ALL PRINCIPAL AREAS

BRIEF SPECIFICATIONS hp 122A

Sweep: 15 calibrated sweeps, 1-2-5 sequence, 5 μsec/cm to 0.2 sec/cm, accuracy ±5%. "Times-5" expander, all ranges. Vernier extends 0.2 sec/cm range to 0.5 sec/cm.

Trigger selector: Internal + or −, external or line. Triggers automatically on 0.5 cm internal or 2.5 v peak external. Displays base line in absence of signal. Trigger level selection −10 to +10 v available when automatic trigger defeated.

Vertical Amplifiers: Identical A and B amplifiers, 4 calibrated sensitivities of 10 mv/cm, 100 mv/cm, 1 v/cm and 10 v/cm; ±5% accuracy. Vernier 10 to 1. Balanced (differential) input available on all input ranges. With dual trace, balanced input on 10 mv/cm range. Input impedance 1 megohm with less than 60 μμf shunt. Bandwidth DC to 200 KC or 2 cps to 200 KC when AC coupled. Internal amplitude calibrator provided.

Function Selector: A only, B only, B-A, Alternate and Chopped (at approx. 40 KC).

Horizontal Amplifier: 3 calibrated sensitivities, 0.1 v/cm, 1 v/cm, 10 v/cm. Accuracy ±5%. Vernier 10 to 1.

Bandwidth DC to 200 KC or 2 cps to 200 KC, AC coupled.

General: 5AQP1 CRT, intensity modulation terminals at rear, power input approximately 150 watts, all DC power supplies regulated.

Price: (Cabinet or rack mount) $625.00.

Data subject to change without notice. Prices f.o.b. factory.

hp now offers 8 different precision scopes

Japanese Tape-Controlled Milling Machine

New three-axis continuous-path numerical control system employs a digital servosystem operating from pulse streams recorded on magnetic tape. Features include a director or "pulse distributor" that is separate from the machine control, a hydraulic servovalve energized by width-modulated square waves, and combined coded discs and logical circuitry feedback.

T. KAIWA and S. INABA
Fuji Tsushinki Mfg. Co. (Japan)

A complete three-axis numerical contouring control system, designed and built domestically, is now available to Japanese machine-tool builders. Like the American Bendix system, the Japanese control is of the incremental, pulse-handling type. Interpolation, however, is performed in a separate director or pulse distributor rather than at the machine tool as is favored by Bendix. The input medium is ½-in. magnetic tape; the feedback transducer is a brush-and-disc pulse generator operating from a precision rack and pinion. The control employs electron tube and transistor logic and is made by Fuji Communication Apparatus Mfg. Co. Ltd.

One of the first applications of the Japanese numerical contouring system has been made to a Makino vertical milling machine intended for operations like cam cutting and die sinking. The table measures 42 x 9½ in.; axis movements are 8 in. longitudinal, 6 in. transverse, and 6 in. vertical. The power actuators are hydraulic cylinders controlled by servovalves. Other applications include a horizontal miller and an automatic lathe for machining automobile worm gears.

The magnetic playback equipment, visible in Figure 1 as an integral part of the machine-control unit, is for the seven-level input tape. One level is for the auxiliary commands of "wait" and "end". Two of the remaining levels are assigned to each of the x, y, and z axes, one for movements in the positive direction and the other for movements in the negative direction. Each pulse recorded in the x, y, z levels represents a discrete increment of movement; thus, the total number of pulses in any given command block and their frequency establish the distance and speed of machine movement.

The magnetic tape handler serves not only to reproduce the command pulses prerecorded on the x, y, and z channels of the tape but also to record simultaneously the feedback pulses generated at the machine slides. The latter feature makes possible automatic return to machine zero simply by reversing the tape and replaying the feedback pulses. The recording facility is made use of also in the record-playback mode, wherein the initial part in a lot is cut on the machine under the guidance of a skilled machinist. From then on, identical parts can be processed automatically under tape control.

While the record-playback feature offers benefits occasionally, this system has been designed specifically for computer programming, as is evident in the system block diagram, Figure 2. The routine begins with the preparation of a process sheet by a tool engineer who lists starting points, coordinates of straight lines, points of tangency, radii of arcs and circles, feed rates, tool size, etc. This data is fed into a Facom-128 computer via a 72-hole tape for linear interpolation and cutter-offset calculations. The Facom-128 is a large general purpose machine employing all relay logic. Its number base is biquinary decimal; word length is 8 decimal digits plus signs and exponents. Cost is about $111,000.

Director operation

The computer output is a second 72-hole tape, which supplies data to the pulse distributor or director, Figure 3, through a decimal-to-binary converter. The distributor records pulses on the magnetic tape in the quantities and frequencies demanded by the path definitions and feed rates. Tape speed is 7.5 in. per sec; maximum packing density is 65 pulses per in. Thus, the maximum command pulse frequency is 500 cps. Based on the prescribed reso-

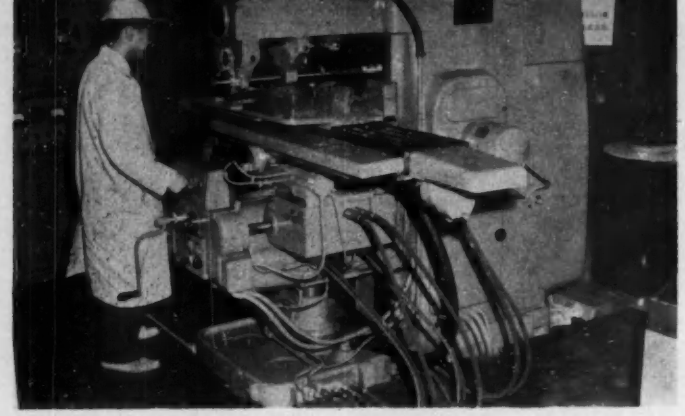


FIG. 1. *Machine for three-axis milling of turbine blades. Numerical control cabinet is at the left.*

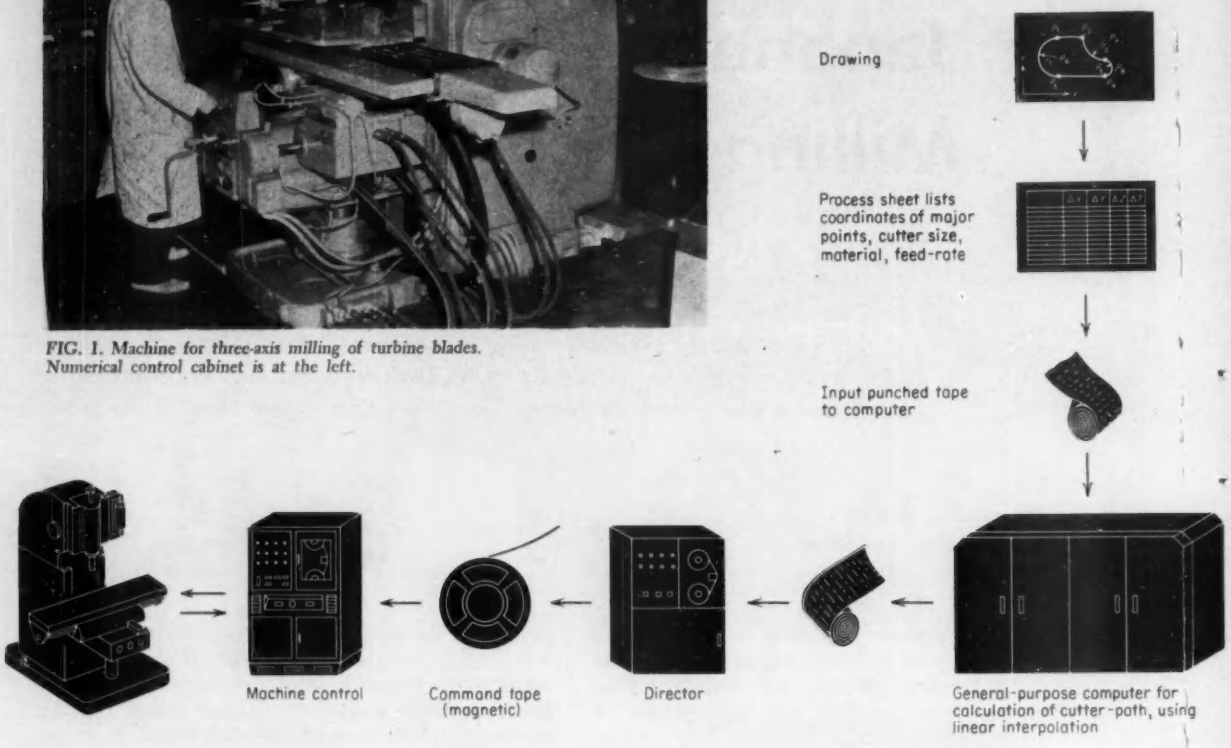

Drawing
Process sheet lists coordinates of major points, cutter size, material, feed-rate
Input punched tape to computer
Machine control
Command tape (magnetic)
Director
General-purpose computer for calculation of cutter-path, using linear interpolation

FIG. 2. *Block diagram of Fuji Tsushinki continuous-path numerical control system.*

lution of 0.01 mm, the limit of feed speed is 5 mm per sec. The pulse distributor is priced at approximately $14,000.

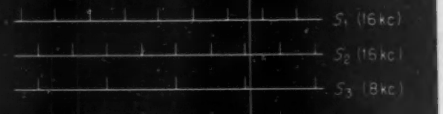
Operation of the pulse distributor is fundamentally digital. The input mechanism is a 72-hole tape reader that accepts the *dx*, *dy*, *dz*, and *dt* values calculated by the computer. The information distributing circuit converts these values from the biquinary numbering system employed in the computer to the 5-2-1-1 director code, as shown in the accompanying table. Entries in the last column are for parity checks. The register serves as a buffer storage; while one set of data is read into the register, the preceding set controls a pulse distributor.

Table of System Codes

Decimal digit	Director (5-2-1-1)					Computer (bi-quinary)						
	5	2	1	1	C	5	0	4	3	2	1	0
0					0	0						0
1			0			0					0	
2		0				0				0		
3		0		0	0	0			0			
4		0	0	0		0	0					
5	0					0						0
6	0		0		0	0					0	
7	0	0			0	0				0		
8	0	0		0		0			0			
9	0	0	0	0	0	0		0				

The source of pulses is the clock seen at the top right of the diagram. The pulses at clock frequency enter the time-selecting gate where they are converted to one of five different frequencies as determined by the *dt* command. The frequency of the pulse train as it emerges from the selecting gates establishes the feedspeed at the machine; thus, there are five possible feedspeeds.

The schematic diagram, Figure 4, reveals how pulses are distributed in correspondence with distance commands. The four output AND gates are controlled by the coded number representing *dx*, *dy*, or *dz*. The balance of the circuit consists of four flip-flops that operate on the incoming clock pulse (at the frequency previously determined by the *dt* command) to break each string of ten pulses into a 5-2-1-1 pattern. As the first input pulse approaches the distributor, the multivibrators are all set as shown in the diagram (the shaded portion represents the section of the flip-flop that is firing). The first pulse transfers flip-flop *A*, generating an output pulse at *A*. The second pulse resets flip-flop A, which then directs a pulse to gates *E* and *F*. Gate *E* is closed, but



F is open (because of the condition of flip-flop D); thus, the pulse is passed to flip-flop B, which then transfers, delivering an output pulse at B. The third input pulse transfers multivibrator A, and an output pulse again appears at A. The input fourth pulse gets through to gates E and F, which are still set as before. Thus, flip-flop B resets, causing transfer of flip-flop C and the appearance of an output pulse at C.

If the examination of Figure 4 is continued, it will be found that for every group of 10 incoming pulses, there appear five output pulses at A, two at B, and one each at C and D. By opening and closing the proper output gates, any number of pulses (from 0 to 9) can be transferred to the magnetic tape recorder.

Machine control

In addition to a magnetic-tape handler, the machine control unit contains the operator's control panel, a test station, the servo electronics, and power supplies. Figure 5 is a block diagram that depicts the relationship of the various subsystems required for operation of the machine. Cost of the complete three-axis machine control (including servovalves, position transducers, and hydraulic power supply) is about $16,000.

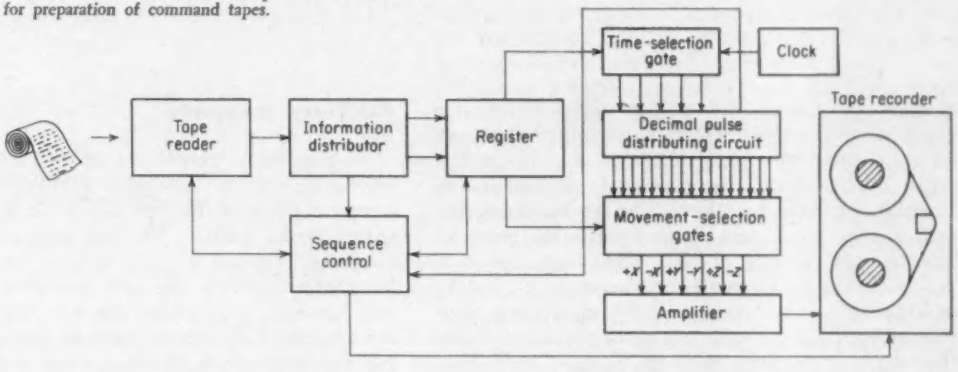
As will become evident with study of this digital servo system, synchronized pulse trains of various frequencies are required for operation of the control. A single pulse generator is the source of all of these trains. The generator output is 32 kc, which is broken down by means of multivibrator circuitry into three separate pairs of pulse trains of 4, 8, and 16 kc. Note from Figure 6 that one train in each pair is phase displaced from the other to prevent coincidence. This feature is essential for portions of the system that carry two or more pulse trains simultaneously; ambiguity could cause false operation.

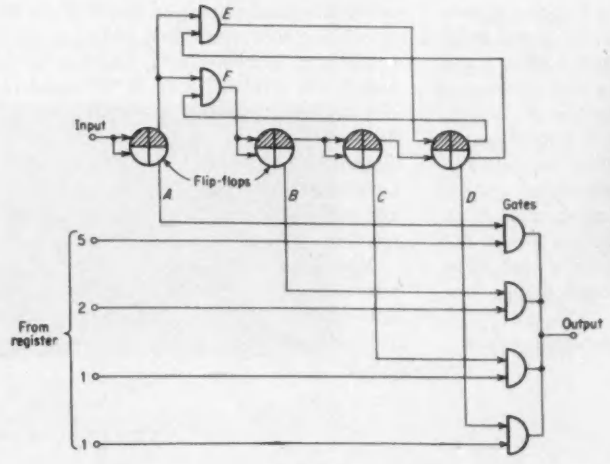
The functions of the various pulse trains are as follows:

S_1—clock pulses for parallel counter (error register)
S_2—16-kc input to stepdown multivibrator
S_3—8-kc input to stepdown multivibrator
S_4—input to feedback devices (position coders)
S_5, S_6—input to circuits for synchronizing tape command signals with counter clock pulses
S_8—input to manual pulse generator for record-playback mode
S_7—input to counter for automatic return to machine zero

As it emerges from the tape-reading circuits, each position-command pulse has some random phase relationship with the clock pulses fed to the parallel

FIG. 3. Schematic of director or pulse distributor for preparation of command tapes.





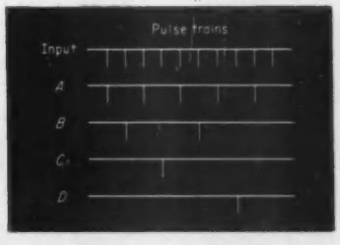


FIG. 4. Logical diagram of the circuit used for converting a coded number into an equivalent number of pulses.

DIGITAL SERVO . . . and ITS PULSE TRAIN TIMING

FIG. 6. Timing diagram for various pulse trains used in machine control system.

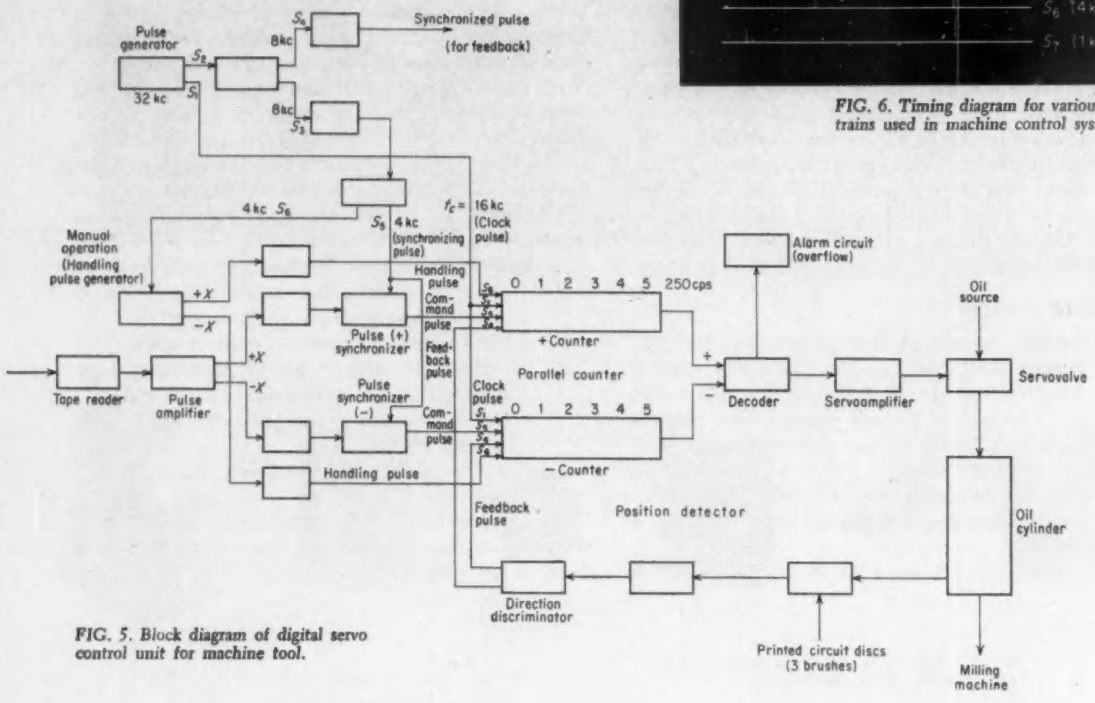


FIG. 5. Block diagram of digital servo control unit for machine tool.

counter. However, the proper operation of the counter requires that the command and clock pulses have an out-of-phase relationship; if such pulses arrive simultaneously the counter is unable to distinguish one from the other. The synchronizing circuit shown in Figure 7 performs the required phasing. It consists of one AND gate and two multivibrators fed by two 4-kc pulse trains (S_5 and S_6 in Figure 6). The function of this circuit is to give one output pulse for each incoming command pulse; the output is in phase with the S_6 train and, thus, out-of-phase with the clock train S_1.

The input pulse transfers the first flip-flop, sending a broad pulse to the gate. When an S_6 pulse arrives, the gate opens to allow a portion of the broad pulse to reach the second flip-flop. When the latter transfers, a pulse is sent back to reset FF_1; and, as soon as the next S_6 pulse arrives, FF_2 immediately resets, delivering the properly synchronized output pulse. Note that the only reason for including the gate and the S_6 train is to prevent the possibility of a command pulse arriving at FF_2 at the same time as an S_5 pulse. Under such conditions, FF_2 would not transfer and the command pulse would be lost. The synchronizing frequency of 4 kc is much higher than the highest command frequency (500 cps); this allows time for the circuit to reset between pulses.

Auxiliary command

As previously stated, one of the magnetic tape levels is allotted to "wait" and "end" commands. The former appears on the tape as a block of pulses time-spaced by 12 millisec. The end commands occur at 8 millisec intervals. The novel logic circuit that differentiates between the wait and end signals and switches each to its proper control channel is shown in Figure 8. The circuit comprises three AND gates and two monostable flip-flops, each with a different time constant. When there are no command signals, gates G_3 and G_2 are closed, but gate G_1 is open because it is kept energized by MM_1 in its stable position. The first command pulse to reach the input terminal is blocked by G_2 and G_3, but is allowed to pass by G_1. Multivibrator MM_1 transfers, opening G_2 directly and triggering an RC network that will flip MM_2 after a 10 millisec delay; gate G_3 remains closed. If the pulse train is for an end command, the next pulse arriving at the input terminal 8 millisec after the first finds G_2 open and G_3 still closed. This results in an output pulse at the E line.

Now assume that the incoming pulse train is for a wait command, meaning that the second pulse will not appear until 12 millisec after the first. After a 10-millisec wait, MM_2 transfers, closing G_1 and

opening G_3. Simultaneously MM_1 times out and the G_2 gate opens. The next pulse at the input terminal finds G_3 open and passes through to the **W output** line. Both G_1 and G_2 are now closed so that this pulse has no effect on the other circuits. After a short delay, MM_2 resets to open G_1 and close G_3.

Error register

The error-detecting section of the digital servo for each of the machine axes consists of two six-bit counters connected in parallel. One of these is assigned to machine motions in the positive direction and the second to negative movements. The three principal inputs to these counters are the 16-kc clock pulses, the feedback pulses, and the command pulses. Assuming that the initial content of both counters is zero, the output from each is a 250 cps pulse train ($16\ kc/2^6$). The output trains, which are 180 deg out of phase, are fed to a simple multivibrator decoder and converted to a symmetrical square wave. As soon as a command pulse is introduced into the register, the symmetry is upset; the result is a width-modulated square wave. The modulated wave persists until the command content of the counter is returned to zero by the arrival of a feedback pulse. The register can accommodate as many as 32 command pulses before "overflowing", at which time an alarm is sounded and the machine controls deenergized. Only in the event of a machine malfunction will the command pulses lag the feedback pulses by 32.

After passing through a push-pull servoamplifier, the width-modulated square wave from the decoder serves to energize a hydraulic servovalve, Figure 9. This valve is of the nozzle-flapper type. When the flapper is centered between the nozzles, the back pressures in the variable-pressure chambers behind each nozzle are equal. The flapper is centered when the symmetrical 250-cps square wave energizes the driving coil. When the balance is upset by the introduction of a width-modulated wave, the mean position of the flapper shifts slightly in one direction or the other. This increases the pressure in one chamber and decreases it in the other. The amount of flapper shift and the pressure differential is proportional to the total error in the summing register.

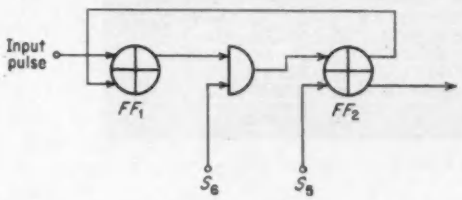


FIG. 7. Logical circuit for synchronizing random command pulses with output of clock generator.

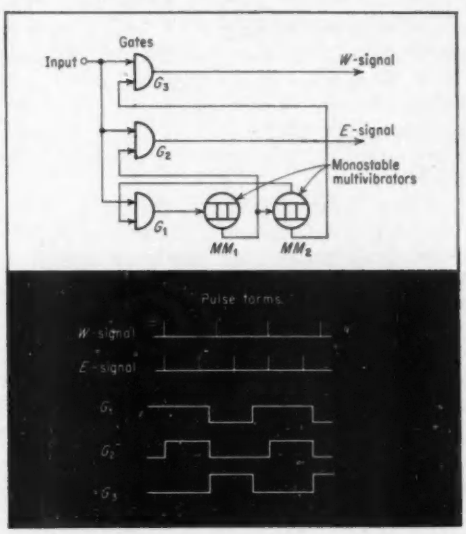


FIG. 8. Circuit for distinguishing between "wait" and "end" siguals, which are recorded on same tape channel.

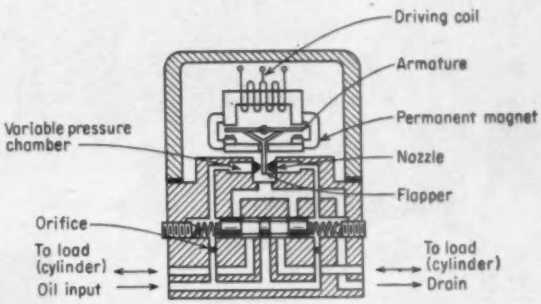


FIG. 9. Cross-sectional diagram of pulse-operated servovalve.

The valve spool is arranged to remain at the valve center when the chamber pressures are equal. As soon as these pressures vary, the spool moves to admit high-pressure oil to the machine actuators. In this way, the speed and direction of machine movement are made to reflect the content of the register.

Position Coder

The position coder assigned to each machine axis for feedback to the error register actually consists of a group of mechanisms, Figure 10. It includes a precision rack fixed to machine table and a gear box that is driven by a pinion in mesh with the rack. The output shaft of the gear box rotates a coder disc carrying printed circuit commutator segments. Three brushes complete the electrical connections to the coder disc; one brush is used to supply positive potential to the disc, while the two remaining brushes serve as reading fingers. Successive commutator segments in each ring on the disc are separated by 1.5 deg. Adjoining segments in the two rings overlap 0.75 deg.

A movement of 0.01 mm along one of the machine

FEEDBACK DISC . . .

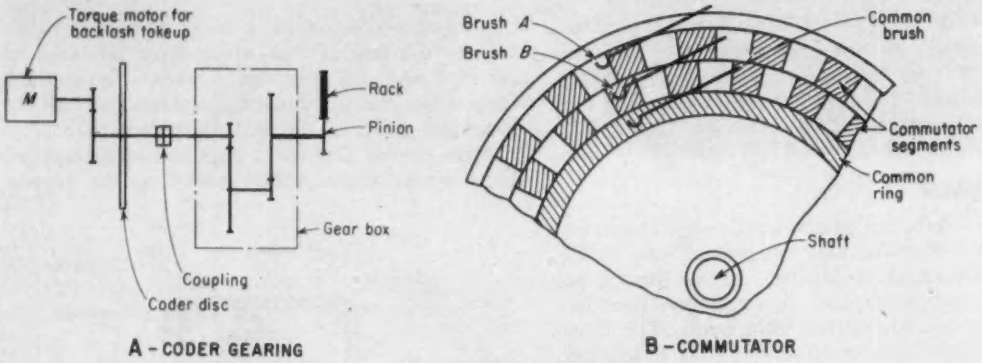


FIG. 10. Position coder for feedback.
A—Diagram of gearing for coupling coder disc to machine slide.
B—Layout of printed-circuit commutator.

. . . and CIRCUITRY

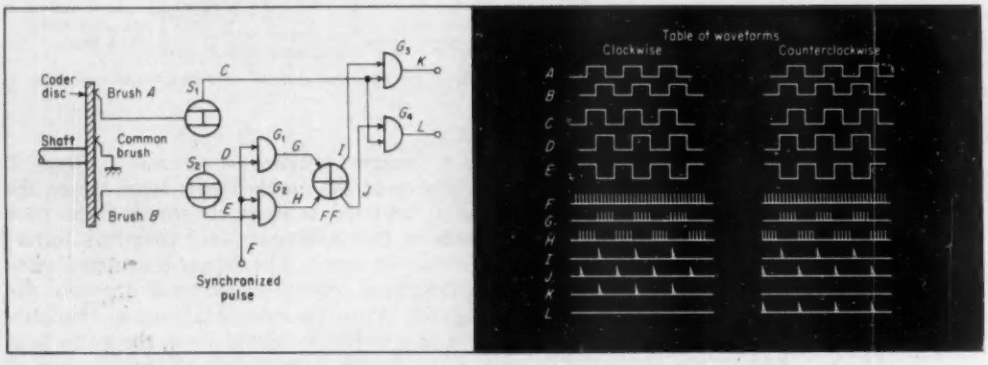


FIG. 11. Schematic diagram of logical procedure for distinguishing between clockwise and counterclockwise rotation of coder disc.

axes causes the disc to rotate through 1.5 deg. Thus, for each 0.01 mm movement, two pulses are dispatched by the coder—one from each ring. In addition to feeding back distance information, the disc makes it possible to discriminate between positive and negative directions of movement. Figure 11 shows the sensing detector or logical circuit that permits this discrimination. Also shown are the wave forms at each point in the circuit. When the coder disc rotates in a clockwise direction, the output pulse appears at terminal A. The output is at terminal *B* if disc rotation is counterclockwise.

For clockwise rotation, the pulse train from brush A leads that from brush *B* by 180 electrical deg (corresponding to 0.75 deg of disc rotation). The pulses from commutator band A are amplified and reshaped in Schmidt circuit S_1; those from band *B* are converted into two mirror-image trains of reshaped and amplified pulses, which alternately open and close AND gates G_1 and G_2. This gating action admits synchronized pulses from *F* first to one side of bistable multivibrator *FF*, and then to the other. The continuous set-reset operation of *FF* leads in turn to alternate opening and closing of the output gates. Gate G_3 is open each time a voltage rise occurs at C (indicating that brush A is in contact with a commutator segment); gate C_4, however, is closed. Thus for clockwise operation, output pulses appear only at terminal *K*.

For counterclockwise operation, the gating action of G_3 and G_4 is exactly the same. Now, however, the square wave from brush *A* lags that from brush *B* so that the voltage rises are gated through to terminal *L*.

The control can be operated manually as well as from tape inputs. For manual operation, coder discs similar to those employed for position feedback are attached to a calibrated dial. When the dial is turned the discs generate pulses, one for each 0.01 mm of movement desired, which serve as input signals to the error register. These same signals can also be switched to the magnetic tape recorder preamplifiers for record-playback of machine motions.

How to Make the Bid Request Pay Off

Preparing a bid request—the first step in buying a complex control system—can be the most important buying function. Doing it right can get the buyer the best system at the lowest cost. Doing it wrong may scare away the best supplier or lead to an inadequate or unnecessarily high-priced control system. Here is a check-list of nine key points to keep in mind when putting together an invitation to bid.

WILLIAM D. BELL, Tucson, Ariz.

A company sent invitations to bid to 58 different manufacturers and received 32 bids. After reviewing the stack of proposals, it reevaluated its requirements based on the free systems engineering received, then sent out completely changed specs to the 32 companies which had bid the first time. Only 14 companies replied the second time. From this group, a single supplier was selected to deliver a $100,000 data system. Since on the average, a supplier spends $3,000 to prepare a proposal for a complex control system, the systems industry spent $138,000 preparing proposals (46 separate bids at $3,000 each) for this $100,000 contract.

Because of the economics involved, a sales manager carefully chooses the invitations to bid. He cannot bid all requests. He picks the ones on which he feels he has the greatest chance of success—because he has compatable equipment to offer, understands the application, has prior experience or designs that will help, or has an "in" with the company. The buyer, on the other hand, wants to encourage the best qualified companies to bid. The object of the bid request is to induce the best suppliers to propose the best system at the lowest cost. Here are nine key factors for the buyer to keep in mind when preparing a bid request.

1. Due Dates

Suppliers need adequate time for preparing bids. Unless the desired control system is very simple, 60 days should be the minimum period. For complex systems, there should be 90 days before due date.

Buyers are rarely so liberal with due dates. Typically, after an organization spends months debating the problems of acquiring a system and justifying the acquisition, it asks manufacturers to supply a definitive, carefully planned, carefully priced bid in 30 days. A buyer that makes such an unreasonable request can suffer. Usually, it is impossible for a sales department to begin work on a bid request the day it arrives. There are other customers and other bid requests, and work has to be scheduled. In effect, short due dates ask the sales manager to make a crash program out of the job.

Buying systems is not like buying production items off the shelf. It takes time for the supplier to evaluate all requirements, engineer special features, and price out the system. Final prices have to be reviewed with higher levels of authority before they can be submitted, and this takes time, too. When a buyer squeezes the supplier in the time allowed, the supplier is forced to protect himself by adding a "fudge factor" to his cost. Frequently the most competent suppliers will make a buyer pay in this way for his lack of consideration.

There is another reason for giving suppliers adequate time. A too-short due date can serve as a warning flag to a sales manager. He may take it to mean that somebody already has the contract sewed up. Many buyer organizations, either because of law or company policy, require that large dollar items, such as control systems, be sent out on open bid. Yet it often happens that a particular company already will have "gotten in bed" with the buyer.

Thus, a decision as to which system to buy has been made long before invitations are sent out.

Although short time schedules are a good way to freeze out competition, minimize confusion and hassling, and guarantee that a purchasing department will not try to force an unwanted system upon the people making the buying decision, they are also risky. Sales managers of the companies who receive such a bid request may be delighted when their own salesmen can work such a caper, but knowing it for a modus operandi turns a too-short or difficult due date into a red flag. If the sales manager interprets a short due date as an attempt to freeze out competition, he'll quickly no-bid the request. And that lessens the chances of getting the best possible system at the most favorable price.

When due dates are too short, manufacturers will request extensions—sometimes even second and third extensions. Granting such extensions is necessary when the number of requests dictates it. But on the other hand, it is unfair to the manufacturer who has strained to meet the first date, and it adds to the buyer's paper work and cost.

2. Define Your Terms

Because standardization of nomenclature does not exist in the systems business, suppliers can spend a great deal of time puzzling over the wording of a bid request. For example, specifying a sampling rate of 1,000 per sec is not enough. What is a sample? Is it one reading of one channel, or is it one reading of all channels in a scanning cycle?

To insure understanding and to make certain the buyer gets the hardware he thinks he is buying, the invitation to bid should clearly define terms that are used. Cycle, sample, frame, operating modes, channels—are all common enough terms, but they can have different meanings to different people.

3. Define Requirements by Function, Not Hardware

It is always difficult to describe adequately in a bid request just what is wanted from a system. *Suppliers will be most impressed with a request if it defines requirements in terms of functions and not in terms of hardware.* Thus, if it is necessary to record digital data on magnetic tape at some prescribed rate, the bid request should not stipulate that a certain manufacturer's tape recorder must be employed to do the job (although stating an equipment preference is all right).

Why not define hardware? There are two important reasons. First, for the buyer to attempt to define a system in terms of the detail hardware demands that his engineers and technical people have the technical knowledge, experience, and competence of all the engineering staffs of all the suppliers who will submit bids. In the rapidly growing dynamic field of control systems, it is highly unlikely that the buyer's engineers will be superior to all the engineering staffs who are specialists in this kind of gear. Besides, the buyer cannot know what is coming out of research laboratories.

There are many times, however, when it is hard to describe operations in terms of function, and clarification can be gained by restating requirements in terms of hardware. This is not only permissible—it is a good idea. However, the buyer should very clearly and emphatically state that hardware details are included for the purpose of defining requirements and are not meant to limit bidders in any way.

When the supplier defines the equipment he intends to use in terms of function, he justifies his selection. In the process of evaluating several bids, the buyer will gain considerable insight into the pros and cons of different configurations and different devices and hardware. This better understanding would not be gained if hardware was rigorously defined in the bid request.

Another point is the possibility of again freezing out competition. A salesman has done his absolute best job when he can persuade a company to issue a bid request that is very narrowly written around the specifications of *his* equipment. As a consequence, a bid request in terms of detailed hardware descriptions may be interpreted as another maneuver to freeze out competition.

4. Explain Intent When Possible

The intention back of specifications may be more helpful than the specification itself. For example, if a bid request specifies a system able to scan 10,000 transducer channels per sec, the *intent* might be to capture a complete sample of all channels in as short an interval as possible, so that the data can be considered as practically instantaneous—not to achieve a high scanning rate for its own sake. A different solution might be to use "sample and hold" circuits which would give a true instantaneous sample when scanned at a leisurely rate.

Manufacturers want to supply a system that will do the job best. They can help the most if the buyer is as clear as possible about what is to be accomplished—not how operations are to be performed.

5. Accuracy Specifications

The size of the system and the jobs it must do will, of course, fix its price level. *But within this configuration the cost will be primarily determined by the accuracy requirements imposed.*

First, the bid request has to spell out what is meant by accuracy. Suppose it specifies 0.5 percent accuracy in the performance of a part of a system. Is this explicit? Not at all! Does it mean rms or peak-to-peak values? There's a significant difference. And can the supplier assume that the buyer really means the error can be plus or minus this amount?

Suppose that the request specifies an overall system accuracy of the data, as recorded at the output, of plus or minus 0.1 percent rms. Is this now explicit? The answer is still no. Is this the accuracy as related to the inputs of the system, excluding long lines to transducers? Does it include the long lines and mean the measurements at the transducer terminals? Or does the accuracy include the transducers themselves? Depending upon the interpretation given to questions such as these, concerning the accuracy specifications, the cost of the final system can fluctuate by many thousands of dollars.

The key on accuracy is to be explicit. There is nothing wrong in defining specifications in terms of rms, peak values, variation around a statistical sigma, or by any other method that is appropriate and understood by the buyer's staff. But the buyer should consider the consequences of ambiguity in the accuracy specifications.

When accuracy specifications are not really clear, the supplier can very reasonably take the attitude that the buyer doesn't really understand his own requirements. The supplier then bids minimal or marginal accuracy as related to the specifications to get low costs, and because his bid is low, he may win the contract, triumphing over other suppliers who tried to meet the letter of the specification. A year later, when delivery is made and acceptance tests are being run, the buyer may take exception to the accuracy of the equipment selected. The supplier will argue that the request did not say what was really meant. And how much of an issue can the buyer make? If he refuses to accept the system, he might have to wait another year to get delivery.

The relationship between cost and accuracy is shown in Figure 1. Obviously, necessary accuracy should be secured to do an adequate job with a system. Just as obviously, unnecessary accuracy imposes an unnecessary cost penalty. In working with digital computers, engineers frequently specify one order of accuracy greater in the calculations that is required in the final data, a reasonably safe rule for computing operations.

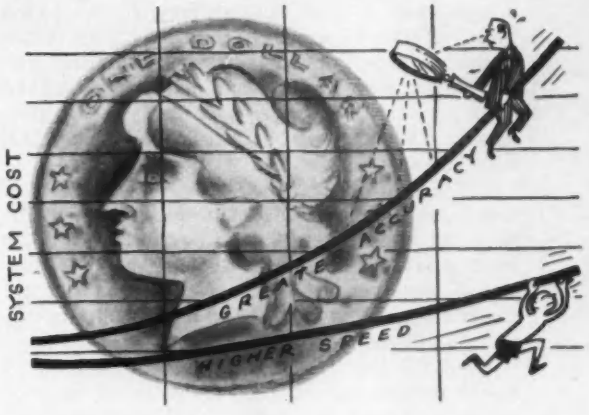
Unfortunately, this same kind of thinking has spilled over into defining hardware specifications. Thus, if requirements are for 1 percent data, and a 0.1 percent system is stipulated, the buyer feels confident that the equipment itself will not introduce errors. This is true, but the cost penalty is excessive. *The two cardinal points relative to accuracy are: (1) define accuracy requirements explicitly, and (2) demand only the accuracy that is really needed and can be justified.*

6. Speed Specifications

Within a given design configuration, the operating speed imposed upon the system will be a second major determining factor in establishing the final cost. Figure 1 also shows the relationship of speed to final cost. This is a more linear relationship than accuracy, which tends to become exponential.

In general, time is money, and higher-speed performance is gained at the cost of additional or more expensive hardware. Here again, *the bid request should define as clearly as possible the speed that is genuinely needed to attain design objectives. When operating speeds are indicated, the amount of tolerance that can be accepted should be stated.*

FIG. 1



For example, a magnetic-tape system is required to transfer 17,500 characters per sec to a compatible IBM 700 series magnetic tape. Standard tape read-write speed for the computing system is 15,000 characters per sec. If the customer is adamant about the 17,500 specification, then the system designer must try to alter the speed characteristics of the tape transport so that it will record at one speed but play back at the slightly slower speed. Or he must incorporate buffer memory equipment to accomplish the speed translation. Both approaches increase costs. It may be better for the customer to restate his needs.

Another customer specifies a rate of switching analog input channels for scanning and conversion to digital form. These requirements can almost be met by the standard equipment specifications of the manufacturer—only the settling time of input filters and the rise characteristics and bandwidth of associated amplifiers are slightly exceeded. To meet the

specifications, the manufacturer must do some additional engineering effort in a very difficult area, or gamble that he can sneak by and still meet the accuracy specifications as stated. If he is wise, the manufacturer will introduce an additional cost factor to cover these uncertainties. On the other hand, if the buyer is willing to give on either speed or accuracy requirements, there can be a significant reduction in the final cost of the system.

7. Reliability

Although every buyer wants the best possible system that he can secure, very few are willing to pay the price of a truly superior system. Most manufacturers believe that too much emphasis is placed on 15 to 20 percent price differentials by buyers. The importance of reliability shows up clearly in the experience of the U.S. Navy, which spends 10 to 100 times the original cost of larger electronics systems to cover their maintenance during life.

The Navy has also found that 80 percent of failures in these systems were attributable to vacuum tubes, yet only 15 percent of the components in this equipment were vacuum tubes. The emphasis that the systems industry is placing upon transistors and other solid-state components promises much more reliable performance. Nevertheless, reliability still must be a major concern of the purchaser.

The manufacturer of a system can supply just about any kind of component reliability that the buyer wants—**and is willing to pay for.** If a buyer wants gold-plated terminals, silicon transistors, completely sealed and purged enclosures, built-in air-conditioning facilities, he can have them for the asking—and the money.

What the bid request should do is to define as well as possible the operating requirements that will be imposed upon the system. What is the consequence of downtime to the operations of which the system will be a part? How long can the user tolerate the system being down? Will maintenance facilities be readily available? The answers to this kind of question help the manufacturer decide whether the buyer wants a Cadillac or a truck.

What is even of more help to the manufacturer —if the buyer can furnish it—is the price range that the buyer thinks will bracket his equipment. Purchasing departments are usually reluctant to release this kind of information. On the other hand, it's unfair to ask a manufacturer to spend his time and money engineering a half-million-dollar system for a buyer who has budgeted to spend only $50,000.

8. Deliveries

The special engineering and nonstandard nature of systems requires long lead times for delivery. Seldom is this shorter than six months, and it may be as long as two years, or longer. Nine to 12 months are probably typical. Here is another case where the buyer can increase the price of the system by a carelessly-worded bid request. If the bid request demands very short-time deliveries, the company that plans to meet the requirements may have to reschedule other work and plan on overtime shifts. That raises the price of the system sharply.

As control systems play a more and more important role, the question of delivery on time grows more and more vital. For a new process plant to go on stream at a certain time, the electronic control system, including loggers, alarming, and computing facilities, have to be ready and available on time; otherwise, a multimillion-dollar operation stalls.

If delivery requirements are stringent, this fact and the reasons behind it should be made clear in the bid request. Further, there should be teeth in the contractual arrangement covering this point. Resulting system costs will be higher, but the buyer will have assurance of on-time delivery.

9. Guarantees

Systems companies typically guarantee their equipment for 90 days. There are companies that give a guarantee covering both labor and material for any failure of their system for a full year. Only rarely do system buyers place guarantees in the proper context when evaluating such factors as performance, specifications, reliability and cost.

From the buyer's standpoint, it would probably be desirable to specify a guarantee that all bidders will meet. This would make bids more uniform and much easier to evaluate. Practically, different suppliers have different bases for their guarantees and warranties, and it would probably be difficult to get such uniform statements.

But again from the buyer's standpoint, the explicit specifications of the system he is buying, including accuracy, speed, performance tests, and delivery, should be spelled out in such a way that he is protected. This can be done within the framework of the contract negotiations. Very surprising is the looseness and ambiguity of the contractual arrangements that are often used to buy systems costing hundreds of thousands of dollars. This lack of definition is unfair to both the buyer and the seller. Reputable system manufacturers will welcome definitive statements of equipment and performance requirements. Such statements assure them of competing fairly with other companies.

Power Switching With Junction Transistors

THE GIST: Junction transistors can be used to switch powers of more than 50 times their rated collector dissipations. Some of the theory of junction transistors in large-signal switching applications is discussed here. Characteristics of primary interest in switching transistor action are the open impedances, closed impedances, and the switching or response time. The relationships presented are adequate for preliminary design planning in large-signal or pulse applications for control circuitry.

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There are three regions of operation that have been established for the junction transistor:

Region I. Collector current cutoff

Both the emitter junction and the collector junction are reverse-biased, and essentially the entire collector power source voltage appears across the collector junction.

Region II. Active region

Low level linear operation with a forward-biased emitter junction and a reverse-biased collector junction.

Region III. Collector current saturation

Both the emitter junction and the collector junction are forward-biased with practically the entire collector power source voltage appearing across the load.

Figure 1 shows these three regions of operation on typical junction collector characteristics for common base and common emitter connections. For class A low-level operation, the no-signal operating point is biased to point *C* on the load line, and the driving current can vary between the limits *B* and *D*. For class B operation, the no-signal operating point is established at a point *B* on the load line, and the driving current can vary from zero to point *D*. The maximum peak collector current in either case approaches a value of E_{bb}/R_L. If the transistor is overdriven and the driving current exceeds the value necessary to cause I_c to approximate E_{bb}/R_L, the tansistor saturates, and Region III conditions exist. When the transistor is used as a switch, Region II conditions exist during the transition time.

When a transistor saturates, an excess concentration of minority carriers occurs at the collector-base barrier. Figure 2 illustrates how minority carrier

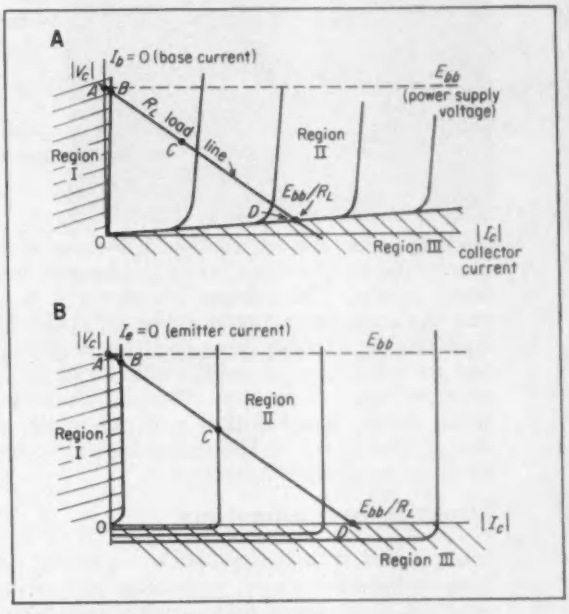

FIG. 1. Transistor collector characteristics. A, common-emitter. B, common-base.

density distribution might appear in the base layer for each operational region. In Region I, due to reverse bias conditions which tend to attract minority carriers from the base layer to the emitter and collector, the minority carrier density on the base side of the junction is essentially zero. In Region II forward bias on the emitter junction causes carrier injection into the base layer with a high concentration in the vicinity of the junction. As before, reverse bias on the collector junction would result in low minority carrier density at this junction, being essentially zero. In Region III operation the tran-

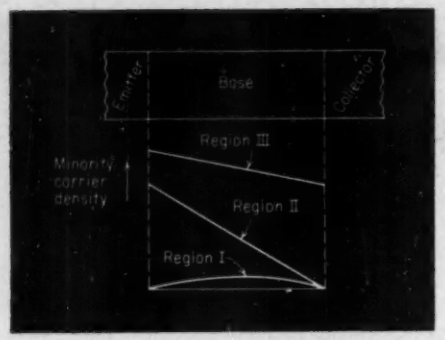

FIG. 2. Base region minority carrier density.

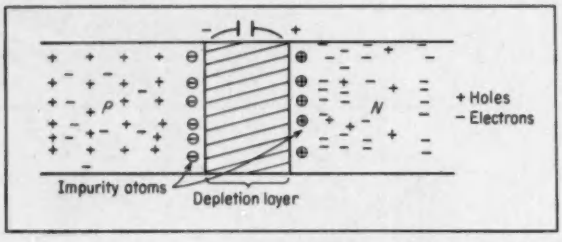

FIG. 3. PN-junction depletion layer effect.

sistor saturates, and the continued injection of carriers by the emitter causes no further increase in collector current. The collector impedance is so low that the collector voltage is extremely small. As a result, all the minority carriers arriving at the junction are not attracted across the collector barrier and most are stored in the base. Thus, a high minority carrier density would exist at both the emitter and the collector junctions. This storage has an important effect on transistor switching times.

Depletion layer capacitance

Coincident with the emitter and collector junctions or transition regions are emitter and collector depletion layers across which emitter and collector bias voltages appear. Under equilibrium conditions (no external applied voltage), a small potential exists across each depletion layer due to an unbalance of charge in the P and N regions near the junction. This unbalance is created by the tendency of holes to diffuse into the N region and for electrons to diffuse into the P region. Thus, a thin layer is produced where hole density is less than in the P region and electron density is less than in the N region.

These mobile holes and electrons do not recombine but produce a net charge density that is related to the difference in energy levels between the conduction band in which the mobile electrons exist and the valence bond band in which the mobile holes move. The exaggerated sketch of Figure 3 simulates the depletion layer effect for the PN junction. The polarity signs associated with the impurity atoms represent the net charge remaining after assimilation of the atom into the crystalline lattice of the respective regions.

Since a potential field exists, the depletion region must have capacitance. This capacitance is that of two parallel plates with a spacing equal to the depletion layer thickness. The depletion layer thickness depends upon the potential across the junction. Thus, with external applied voltage, the depletion layer thickness will vary with a corresponding variation in depletion layer capacitance. An increase in reverse voltage causes an increase in depletion layer thickness with a decrease in depletion layer capacitance, while a forward voltage increase would have the opposite effect. Depletion layer capacitance ordinarily becomes significant only at high frequencies or saturation conditions. Depletion layer capacitances effectively shunt the input and output admittances of a transistor and contribute to rise and fall times when the transistor is used as a switch.

Since emitter and collector currents in a transistor are not equal, there must be some current that flows through the base region parallel to the junctions. Under saturation conditions or at high frequencies, a term described as base-spreading resistance is applied to the base layer characteristics. The base-spreading resistance is the majority carrier resistance of the base region and is the sum of resistances which represent voltages fed back to the emitter junction. For large

LARGE-SIGNAL DYNAMIC EQUIVALENTS

FIG. 4. Switching impedances, common-base connection.

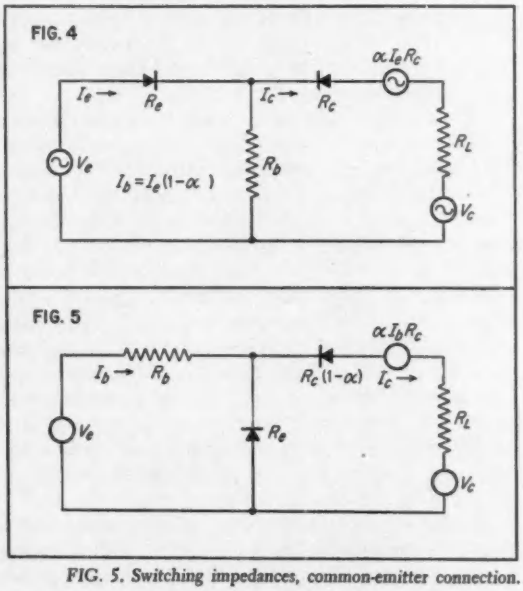

FIG. 5. Switching impedances, common-emitter connection.

signal considerations, frequency dependence of this parameter is of secondary importance, and the base parameter may be validly represented as a resistance whose value in the saturation region approaches a factor of ten less than the active region value.

Input and output impedances

The extreme impedances associated with completely nonconducting (Region I) and saturated (Region III) conditions of the transistor are important when the transistor is used as a switch.

The large-signal dynamic equivalent circuits of Figure 4 illustrate the impedance relationships in the open- and closed-switch conditions. The emitter and collector junctions are shown as diodes with polarities as for a PNP transistor. The input impedance is:

$$\frac{V_e}{I_e} = R_e + R_b(1 - \alpha) \qquad (1)$$

In Region I the emitter junction is reverse biased and $I_e \cong I_{eo}$ (open collector and emitter current). Under these conditions the current gain $\alpha \cong 0$ and R_e is essentially the reverse resistance of the emitter diode; thus, the input impedance in Region I,

$$Z_{in(I)} \cong R_{er} + R_b \qquad (2)$$

Since R_{er} is generally much larger than R_b, the input impedance under transistor OFF conditions is the reverse emitter diode resistance with a value of hundreds of kilohms and would present essentially an open circuit to a low impedance source for either the grounded base or grounded emitter connection.

Open-switch input impedance, $Z_{in(I)} \cong R_{er}$

The output impedance in Region I is the reverse bias resistance of the collector diode. That is, for a reverse bias voltage on the collector and emitter, $I_c = I_{co}$, and the collector junction resistance is the reverse collector diode resistance, R_{cr}. For the grounded base connection, $R_b << R_{cr}$, and the ac output impedance is approximately R_{cr}. For the grounded emitter connection, as in Figure 5, with zero base current, $I_c = I_{co}/1 - \alpha$. I_{co} is open emitter collector current. In this instance, the output impedance, being inversely proportional to the collector current, would be about $R_{cr}(1 - \alpha)$. Increasing the base current in a reverse direction would make $I_c < I_{co}/1 - \alpha$ and the output impedance increase proportionately.

Open-switch output impedance,

Grounded-base, $Z_{out(I)} \cong R_{cr}$
Grounded-emitter, $Z_{out(I)} \cong R_{cr}(1 - \alpha_n)$

In Region III the transistor is in the completely ON condition, and impedance representations become somewhat more complicated. However, for simplicity, the equivalent circuits of Figure 4 and Figure 5 will be used again. In the saturation region, both the emitter and collector junctions are forward biased. The collector resistance under these conditions is very much less than a typical load resistance.

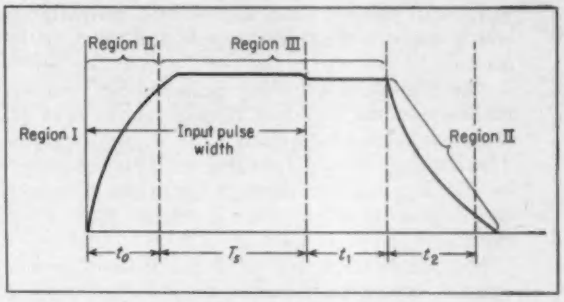

FIG. 6. Collector current switching response.

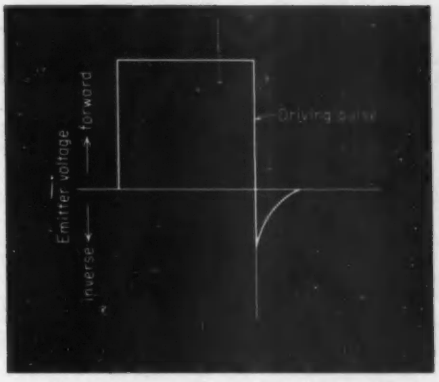

FIG. 7. Driving pulse for improving turn-off time.

The input impedance as given by the following equations for grounded base and grounded emitter, respectively,

$$Z_{in} \cong R_e + R_b \frac{R_c(1 - \alpha) + R_L}{R_e + R_L}$$

and

$$Z_{in} \cong R_b + R_e \frac{R_e + R_L}{R_c(1 - \alpha) + R_L}$$

simplifies to $Z_{in} \cong R_b + R_e$. (3)

since α approaches zero in Region III. Also, under large current conditions R_e becomes negligible and the input impedance reduces to the following:

Closed-switch input impedance, $Z_{in(III)} \cong R_{b(s)}$ (4)

The $R_{b(s)}$ of Equation 4, however, is the base-spreading resistance described previously and is less than the active region base resistance by a factor of ten.

Switching response considerations

An additional junction transistor characteristic of primary interest is the switching time required to change the operating point from Region I to Region III, or vice versa. Figure 6 shows typical collector current response to a large input current pulse. Total response is broken down into three parts: 1) turn-on or rise time t_0; 2) the difference between input pulse

width and turn-on time T_s ; and 3) turn-off time which consists of storage time t_1 and decay or fall time t_2.

The turn-on or rise time, t_0, is the time required for the response to attain Region III status or the time required for I_c to reach 0.9 of its limiting value. The limiting value of I_c in Region III is determined by E_{bb}/R_L; and the transition between Region II and Region III occurs when I_c reaches about 0.9 of the E_{bb}/R_L value.

The following rise-time expressions have been developed, in which α_n is the normal alpha current gain, and ω_n is the normal alpha cut-off frequency:

Common-base rise time, t_0

$$t_0 = \frac{1}{\omega_n} \ln \frac{\alpha_n I_E}{\alpha_n I_E - 0.9 I_c} \tag{5}$$

If the amplitude of the driving current I_B is not sufficient to attain Region III conditions, $\alpha_n I_c \cong I_c$ and Equation 5 becomes:

$$t_0 \cong \frac{2.303}{\omega_n} \tag{6}$$

Common-emitter rise time, t_0

$$t_0 = \frac{1}{\omega_n(1-\alpha_n)} \ln \frac{I_B}{I_B - \dfrac{0.9(1-\alpha_n)I_c}{\alpha_n}} \tag{7}$$

Note that for an amplitude of I_B insufficient to attain Region III conditions, $\alpha_n I_B/1-\alpha_n \cong I_c$ and Equation 7 becomes

$$t_0 \cong \frac{2.303}{\omega_n(1-\alpha_n)} \tag{8}$$

From Figure 6, T_s is essentially the difference between t_0 and the width of the input pulse and represents a portion of the response in the current saturation region. If T_s is comparatively long, I_c will approach its limiting value of E_{bb}/R_L. If T_s is comparatively short, I_c may not reach much more than 0.9 of its limiting value.

The turn-off transient has two components, storage time and decay time. Storage time represents the time between removal of the input pulse and entrance of collector current response into Region II, and is a function of the degree of minority carrier density or storage in the collector junction region. Degree of minority carrier storage is, in turn, a function of the driving pulse width. Storage time, t_1, may be defined as the time required for minority carrier density in the collector region to approach zero. Briefly, the current emitted by the emitter falls to zero as the input pulse falls from its maximum value to zero or reverse current. But the decay of the excess carriers in the base layer at the collector junction maintains the collector current essentially constant until the minority carrier density approaches zero. Then the collector junction becomes a reverse-biased high impedance, and control of the turn-off transient is taken over by the region parameters.

The portion of the turn-off time determined by active region parameters is called decay or fall time, t_2, and is considered as the time required for the load current to decay to 0.1 of its saturation region value after active response of the collector current has begun.

Common-base storage time, t_1,

$$t_1 = \frac{1}{\omega_i(1-\alpha_i)} \ln \frac{\alpha_n(I_{E2} + I_{E1})}{I_c + \alpha_n I_{E2}} \tag{9}$$

Common-emitter storage time, t_1,

$$t_1 = \frac{1}{\omega_i(1-\alpha_i)} \ln \frac{I_{B1} + I_{B2}}{\dfrac{I_c(1-\alpha_n)}{\alpha_n} + I_{B2}} \tag{10}$$

where I_{B1} and I_{B2} are drive-current values before and after turn-off step application, respectively, as are I_{E1} and I_{E2}. The term α_i is the inverse alpha current gain (collector as emitter and emitter as collector), and ω_i is the inverse alpha cut-off frequency.

Common-base fall time, t_2,

$$t_2 = \frac{1}{\omega_n} \ln \frac{I_c + \alpha_n I_{E2}}{0.1 I_c + \alpha_n I_{E2}} \tag{11}$$

Common-emitter fall time, t_2,

$$t_2 = \frac{1}{\omega_n(1-\alpha_n)} \ln \frac{I_c - \dfrac{\alpha_n I_{B2}}{1-\alpha_n}}{0.1 I_c - \dfrac{\alpha_n I_{B2}}{1-\alpha_n}} \tag{12}$$

The preceding relationships are applicable to both PNP and NPN junction transistors. Absolute values of current may be used.

When minimum response is desirable, it is possible to substantially reduce the turn-off time by applying a reverse voltage at the turn-off edge of the driving pulse (Figure 7). This has the effect of accelerating the removal, through strong attraction by reverse emitter junction potential, of excess minority carriers stored in the base region. Thus, the hastened removal of the minority carrier charge will result in more rapid decay of the collector current and a shorter turn-off time. The inverse emitter voltage rating limits the extent to which the driving pulse may be reversed.

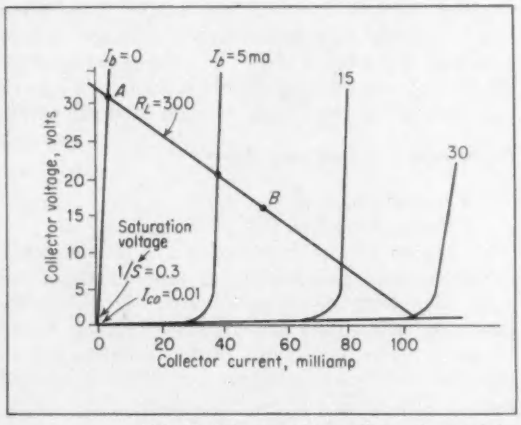

FIG. 8. Common-emitter collector characteristics.

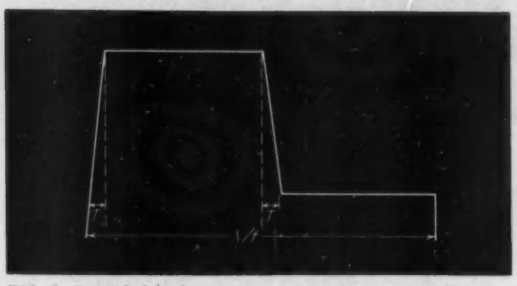

FIG. 9. Simplified load current wave form for one period.

The most important single parameter affecting response to a driving pulse is the cutoff frequency of alpha. Rise times of less than $2.3/\omega_n$ for the grounded base and $2.3/\omega_n(1-a_n)$ for the grounded emitter are relatively easy to attain. Fall times of the same magnitude as the rise times are also attainable if carrier storage effects are minimized. A transistor with a high alpha cutoff frequency is essential in applications requiring fast response times.

In general the grounded base transistor will permit faster total response than will the grounded emitter transistor. However, if speed of response is not critical, a larger load current can be controlled with smaller drive current using the grounded emitter transistor.

Switching powers

Load powers over 50 times the rated dissipation of the transistor are feasible in switching applications. This is easily illustrated by the common emitter characteristics of Figure 8. At point A the transistor is cut off and the collector dissipation is approximately 30 volts times 0.01 ma = 0.3 mw. At point C the transistor is saturated and the collector dissipation is about 0.3 volt times 100 ma = 30 mw. Total transistor dissipation would include emitter dissipation, which, assuming a reasonable emitter saturation voltage of 1 volt and base current of 20 ma, would be about 20 mw, making a total of about 50 mw. The load power at saturation is

$$\frac{E_{cc}^2}{R} = \frac{(30)^2}{300} = 3 \text{ watts.}$$

Thus, a load power is being handled that is 60 times the transistor dissipation. This is an indication of the extremely efficient control of higher powers using transistors as switches.

The transistor suffers a peak dissipation of 750 mw at point B in Figure 8. Thus, it is essential for efficient use of the transistor that the transition from cutoff to saturation be fast enough to keep the average transistor dissipation below its rated value.

Assuming a load current waveform as in Figure 9, the transition dissipation can be averaged over one cycle. T represents the transition time while $1/f$ is the time for one cycle.

The power for the transition period, T, is the integral $\int_0^T ei\,dt$.

Since there are two transition periods in one cycle, the integral becomes $2\int_0^T ei\,dt$,

and averaging over one cycle produces

$$P_{avg} = 2f\int_0^T ei\,dt \qquad (13)$$

The terms e and i are time functions of the collector voltage and current respectively and, from Figure 10, are approximately equivalent to

$$e = E - \frac{Et}{T} \quad \text{and} \quad i = \frac{Et}{RT}.$$

Substitution in Equation 13 results in

$$P_{avg} = \frac{2fE^2}{TR}\int_0 \left(t - \frac{t^2}{T}\right) dt \qquad (14)$$

R = load resistance, R_L $\qquad$ E = power supply, E_{bb}

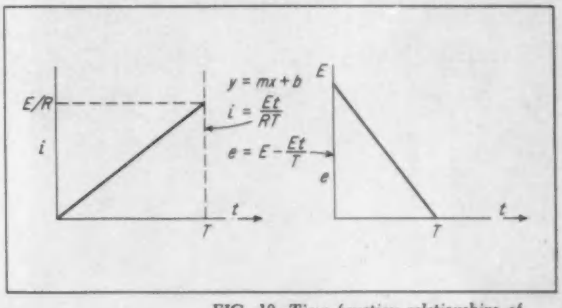

FIG. 10. Time function relationships of collector voltage and current.

Integration of Equation 14 gives the relationship for transition power averaged over one cycle,

$$P_{avg} = \frac{fTE_{bb}^2}{3R_L} = \frac{fT}{3} P_{load} \qquad (15)$$

where P_{load} is the peak load power. Note that this transition power does not include the emitter junction dissipation, but refers primarily to collector dissipation which most manufacturers use for rating.

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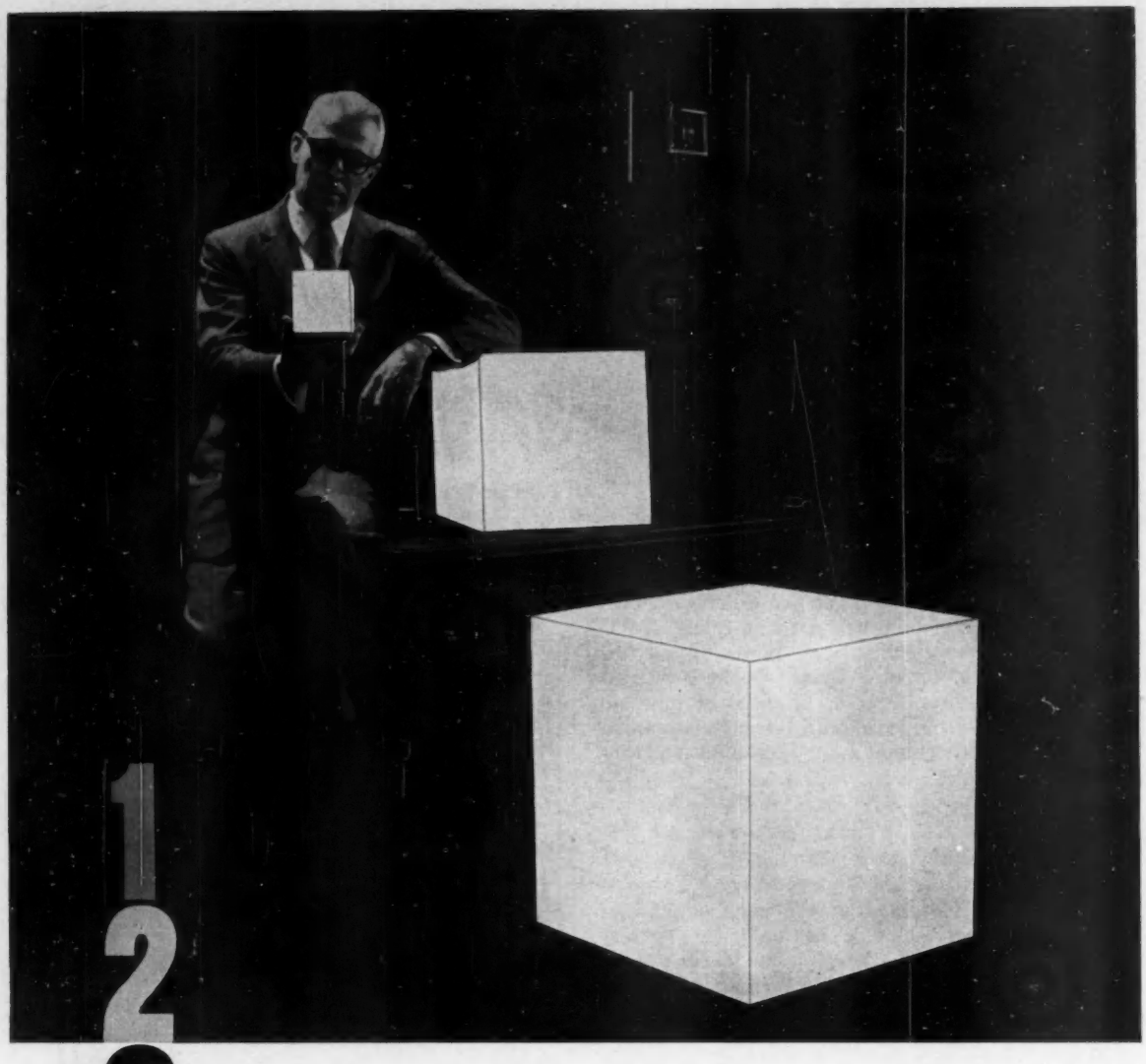

3 generations of airborne digital computers (but we can't show you their configurations)

In the photo above, the three ARMA computers have been intentionally deleted. But the cut-outs accurately represent the relative size of the three generations of ARMA airborne digital computers.

The larger size has been *in production* since 1957. The middle-sized one (a quarter the size of today's) will be in production in 1960. And the micro-miniaturized version in the engineer's hand will be operational in 1962—only .3 cubic feet in volume.

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Using the Root Locus —Part II

THE GIST: Part I of this article *(Control Engineering*, October '59, page 96) described construction of root-locus diagrams and their use in closed-loop stability analysis. Part II shows how to calculate step and transient response characteristics from the locus curve, and how to apply the method to multiloop systems.

T. JAWOR, Evershed & Vignoles, London

The characteristic equation of a general single-loop system $F(s)$ with forward transfer function $G(s)$ and a feedback element $G_F(s)$ is

$$1 + G(s)G_F(s) = 0 \qquad (1)$$

The root locus for such a system is obtained from the poles, zeros, and singularities of $G(s)$ and $G_F(s)$ (see Part I of this article).

When a feedback system $F(s)$ is itself a part of a larger feedback system $W(s)$, as shown in Figure 1, then the root locus of $W(s)$ will have as its starting points the roots of $F(s)$ (for a given value of the loop gain of $F(s)$), and the poles of the remaining elements of $W(s)$. Thus a root locus of $F(s)$ must be constructed and the loop gain of $F(s)$ chosen before undertaking the main root locus of $W(s)$.

A cascade system for controlling furnace temperature can be taken as an example of a multiloop system, see Figure 2A. The fuel flow control loop $F(s)$ consists of the flow controller 2, the flow rate measuring element 4, control valve 5, and a section of the supply pipe between elements 4 and 5. The main temperature control loop $W(s)$ consists of a temperature controller 1, which resets controller 2, the temperature measuring element 6, the furnace 3, and the subsidiary loop $F(s)$. The block diagram of the system is shown in Figure 2B; $R(s)$ is the desired temperature, $C(s)$ the actual temperature, and $U(s)$ a supply disturbance.

The two root loci are shown in Figures 2C and 2D, and the two complex poles and one real pole (the one furthest to the left) of $W(s)$ in Figure 2D being the roots of $F(s)$ for $K = K_1$. Note that the gain $K = K_2$ in the flow control loop will make both $F(s)$ and $W(s)$ unstable with other poles and zeros of $W(s)$, as shown in Figure 2D.

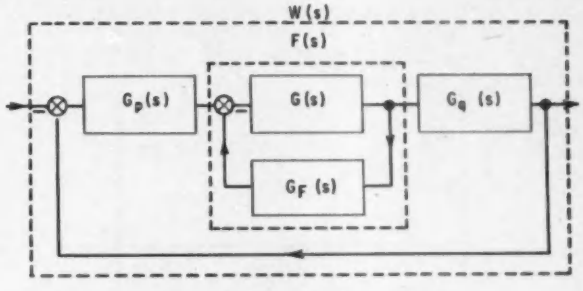


FIG. 1. In a multiloop system W(s), the locus of the subsidiary loop F(s) must be determined first and the loop gain of F(s) chosen before constructing the locus of W(s).

Transient response by root locus

The transient response of a system $F(s)$ consists of a sum of exponential terms of the form $A_j e^{s_j t}$, each arising from a root of the characteristic equation, where s_j is the location of the root P_j, and A_j is a coefficient which can be determined by a graphic technique similar to that employed to find the value of the gain parameter K on the locus, as described in Part I.

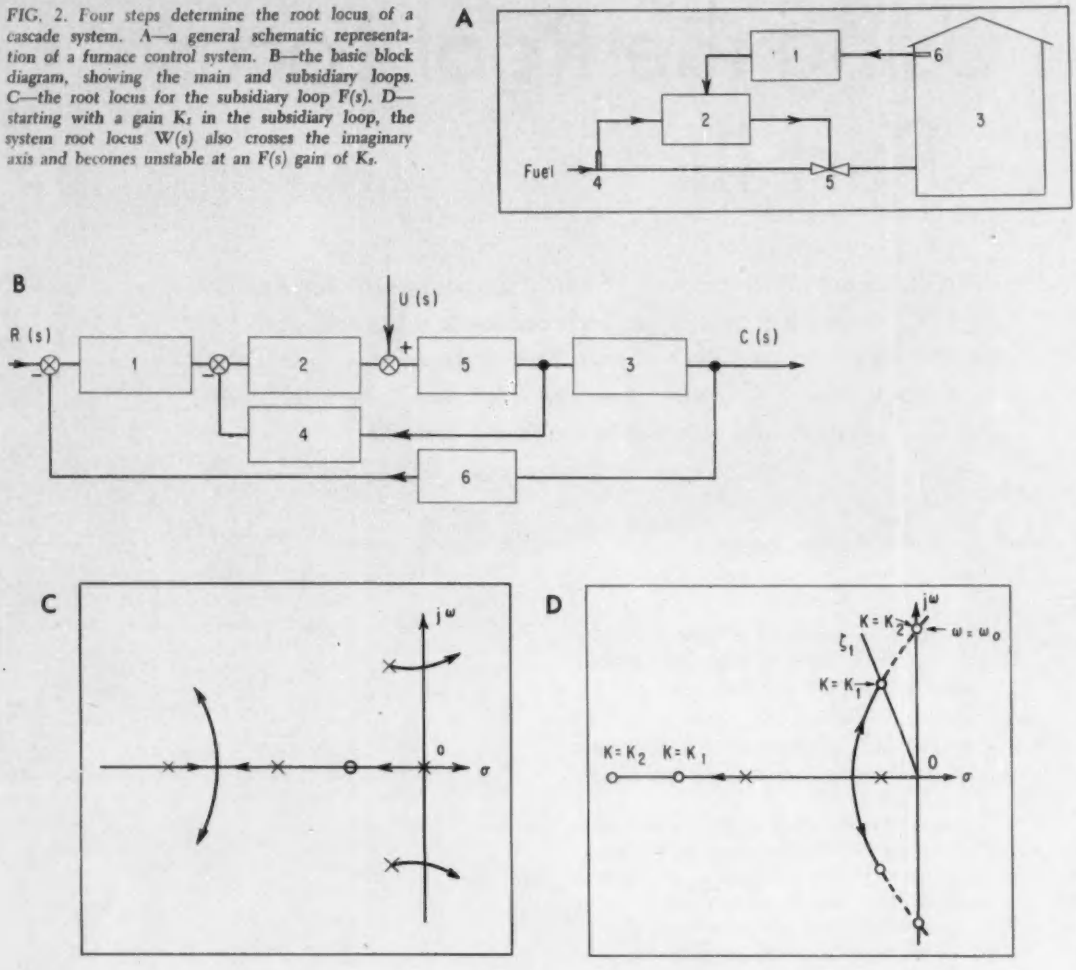
In the following section, an impulse and step response will be considered for a first-order real root and a pair of complex conjugate roots.

Impulse response

A transcendental function gives rise to an infinite number of roots. Here, however, only the roots located on the branches nearest the origin will be considered. This simplification is justified for stable systems satisfactorily damped, since negative real parts of roots remote from the origin are large compared with the same parts of roots close to the origin.

Now, coefficient A_j of the impulse response due to

FIG. 2. Four steps determine the root locus of a cascade system. A—a general schematic representation of a furnace control system. B—the basic block diagram, showing the main and subsidiary loops. C—the root locus for the subsidiary loop $F(s)$. D—starting with a gain K_1 in the subsidiary loop, the system root locus $W(s)$ also crosses the imaginary axis and becomes unstable at an $F(s)$ gain of K_2.



a real root at $s = P_j$ is

$$A_j = [(s - P_j)\,F(s)]_{s=P_j} \tag{2}$$

$$A_j = KA\,\frac{\prod_{i=1}^{u} |Z_i - P_j|}{\prod_{i=1}^{n} |P_i - P_j|}\,|G_B(P_j)|, \quad i \neq j \tag{3}$$

where K is the gain when one of the roots of the characteristic equation is at $s = P_j$, P_i is some other root, Z_i is a zero of $F(s)$, and

$$A = \frac{\prod_{i=1}^{n} (0 - P_i)}{\prod_{i=1}^{u} (0 - Z_i)} \quad \text{for all values of } i \tag{4}$$

The zeros of $F(s)$ are located at the zeros of the forward transfer function $G_A(s)$ and at the poles of the feedback function $G_F(s)$. Thus, u is the total number of factors in the numerator of $G_A(s)$ and denominator of $G_F(s)$. The factor

$$A\,\frac{\prod_{i=1}^{u} |Z_i - P_j|}{\prod_{i=1}^{n} |P_i - P_j|}$$

involves vectors from points $s = Z_i$ and $s = P_i$ (including the point $s = P_j$) to the origin and to the point $s = P_j$. These vectors can be measured off the root locus and the result substituted in Equation 3.

$|G_B(P_j)|$ is obtained by substitution of P_j for s in the modulus of $G_B(s)$. Complex roots occur in conjugate pairs and their coefficients can be combined, giving for the pair at $s = \sigma_i \pm j\omega_i$ a response term

$$c_i(t) = 2A_i[\cos(\omega_i t + \arg A_i)]e^{\sigma_i t} \tag{5}$$

Step response

The coefficients of terms in a step response are obtained somewhat in the way that the coefficients in the impulse response are found. A unit step (trans-

form $1/s$) cancels the factor $(-P_j)$ in Equation 4. Thus the sign of A in Equation 3 is reversed and its modulus altered. Apart from this, the calculation is performed the same as for the impulse response.

As an illustration, Figure 3 shows a system with three roots, P_1, P_2, P_3. The vectors involved in the determination of A_3, the coefficient in the response due to the root at $s = P_3$, are L, M, N, Q, R.

$$\text{For impulse response, } A_3 = \frac{MNR}{LQ}$$

$$\text{For step response, } A_3 = \frac{-MN}{LQ}$$

The response due to roots at $s = P_1$ and $s = P_2$ is

$$c_1(t) = 2A_1[\cos(\omega_1 t + \arg A_1)]\, e^{\sigma_1 t}$$

where $A_1 = \dfrac{MNR}{s(-L)}$ (for impulse response)

or $A_1 = \dfrac{NR}{180\, s(-L)}$ for step response

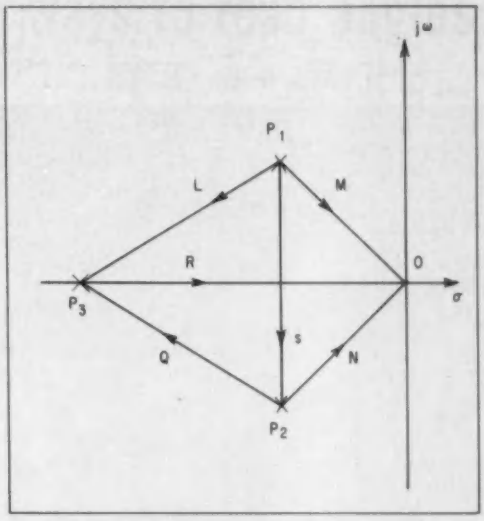
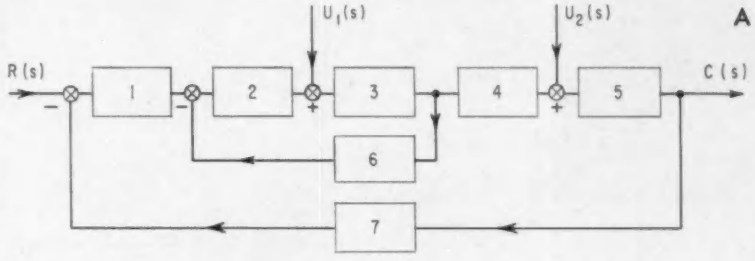


FIG. 3. Transient response coefficients in a system are determined from the evaluation of the vector moduli between the system's roots.

Disturbance response

The foregoing method for determining transient response is applicable for finding the system response to transient disturbances entering at any point in the



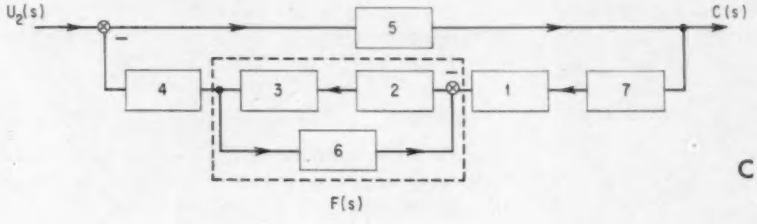
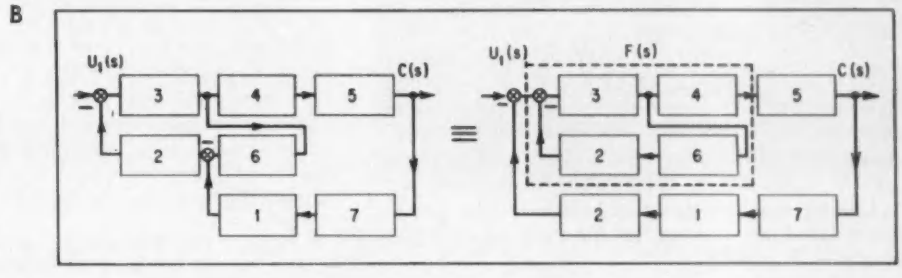


FIG. 4. A—Basic system with disturbances U_1 and U_2. B—System rearranged to show feedback paths for disturbances entering the system at U_1, and C—at U_2. The transient response to such disturbances can be calculated from the roots of these rearranged systems.



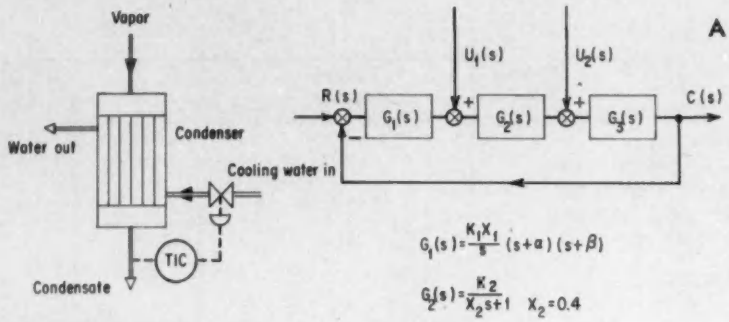
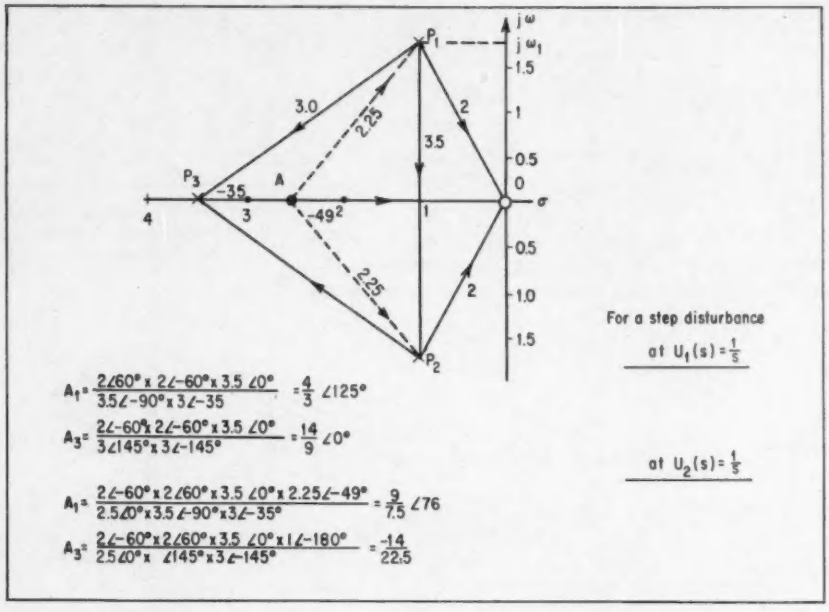


FIG. 5. In this system a three-term controller maintains the condensate temperature constant. Plotting roots gives the transient coefficients for disturbances entering the system as variations in cooling-water temperature or vapor temperature. Substitution of the coefficient in Equation 5 gives the system response to such disturbances.

THE SYSTEM . . .

B

. . . AND ITS LOCUS



control loop. Since the poles of feedback elements supply additional zeros to the transient response, it is necessary to determine the elements constituting the feedback path as far as the disturbance is concerned. A rearrangement of Figure 4A shows clearly the difference in feedback paths between the supply-side disturbance $U_1(s)$, Figure 4B, demand-side disturbance $U_2(s)$, Figure 4C, and reference signal $R(s)$.

To demonstrate the method, a simpler single loop system (Figure 5A) is considered. $G_1(s)$ is a controller and $G_2(s)$ is a control valve admitting cooling water to a countercurrent condenser $G_3(s)$ which serves to condense vapor from a fractionating column ($G_3(s)$ has no zeros.) The temperature of the condensate $C(s)$ is the controlled condition; $U_1(s)$ is the disturbance in cooling-water head or temperature (supply-side disturbance), and $U_2(s)$ is the disturbance of vapor rate or temperature (demand-side).

Having nondimensionalized with respect to the condenser time constant, let the roots be located as shown in Figure 5B.

For both disturbances the controller is in the feedback path. Thus its pole at $s = 0$ contributes a zero at the origin. The response to a unit step $U_1(s)$ is

$$\frac{c(\tau)}{K_1K_2X_1} = -2.67\cos(100\tau + 55°)e^{-\tau} + 1.55e^{-2.5\tau}$$
$$\text{(—imaginary roots—)} + \text{(real root)}$$

(where τ is the nondimensional time) since the zero at the origin and the step canceled one another. Similarly, the response to a unit step disturbance $U_2(s)$ is

$$\frac{C(\tau)}{K_1K_2X_1} = 2.4\cos(100\tau + 76°)e^{-\tau} - 0.62e^{-2.5\tau}$$

since there is an additional zero at $s = -\frac{1}{T_2}$ (point A) contributed by $G_2(s)$.

These results obtain directly and quite simply from application of Equations 3, 4, and 5, by way of simple vector summations as shown in Figure 5. (The $\omega_1 t = 100\ \tau$ term derives from the time constant ratios used to nondimensionalize the locus.)

The author would like to thank E. D. May for assisting in the preparation of these articles.

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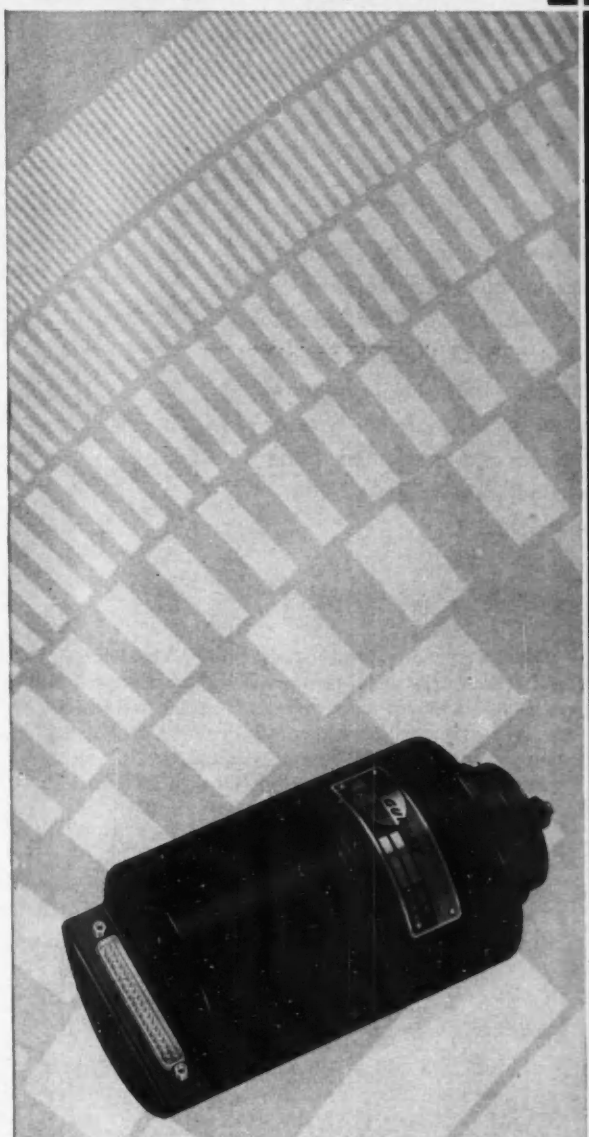

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Progress report on OPCON:

Dow Evaluates Optimizing Control

The first Westinghouse OPCON was installed on a Dow catalytic chemical process as a joint evaluation project of this type of optimizing control operation. Here, the user reports on the success of the installation, which depended not only on OPCON but also on the appropriate selection of associated instruments and controls. The trial installation indicates that both the technical and economic aspects of this type of optimizing control look favorable for pilot plant and production plant installations. However certain prerequisite conditions do exist for any application, and these are listed by the authors.

J. W. BERNARD
F. J. SODERQUIST
The Dow Chemical Company

The Westinghouse OPCON optimizing control used in Dow's evaluation employs a rather simple concept which recognizes that complex processes have been successfully operated for many years by human operators—who do not know the mathematical relationships of the many factors that affect the process but only know the cause and effect relationship in making process adjustments. The optimizing control does essentially what the operator does, but with the advantages of being able to do it faster, more reliably, and with a more complex strategy.

The OPCON control (Ref. 1 and 2) is essentially a special purpose computer with analog input and output. It contains a comparison and memory section, a logic section, and an output section, with a timer to initiate the operating cycle. In addition, it has checking and indicating sections and various operational controls for setting up the unit, determining the input variable incremental move size, and handling cases of moving against the process limits.

OPCON operates by continually experimenting with the process to find and hold its optimum performance level. The OPCON control, Figure 1, varies one or both of the controlled inputs X_1 and X_2, waits until the new output conditions stabilize, measures the output Z, and then compares this output to previous values (base-point) to determine whether or not it has improved the process performance. A base-point recorder, fed from the control, records the last best value of Z. The OPCON control keeps repeating this experimental cycle to hold the output criteria at its optimum level despite the effect of uncontrolled disturbances U_1 and U_2.

The evaluation of the Westinghouse OPCON control on a chemical process was established as a joint project by The Dow Chemical Co. and Westinghouse Electric Corp. Dow provided the chemical process located in suitable laboratory facilities (mini-

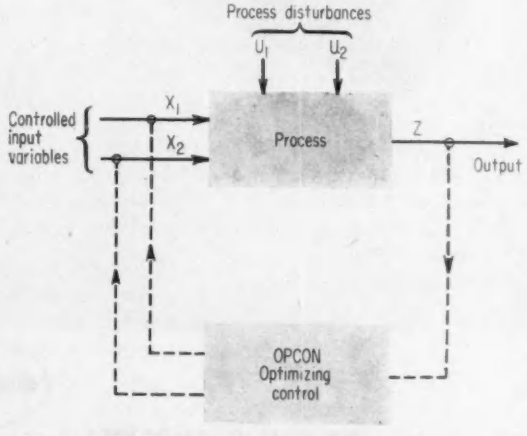


FIG. 1. Simplified connections between OPCON and the process it optimizes. Not shown, but discussed in the text, are the individual control loops for the controlled input variables and the equipment and requirements for measuring the output or optimizing criterion.

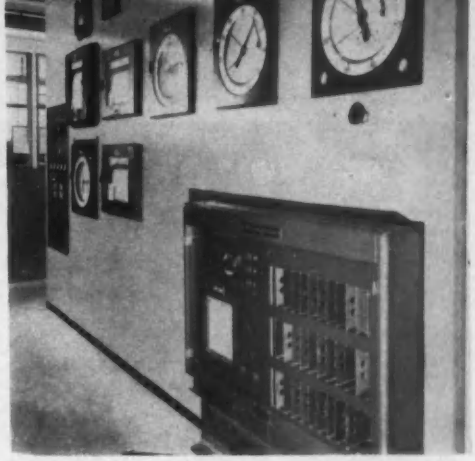
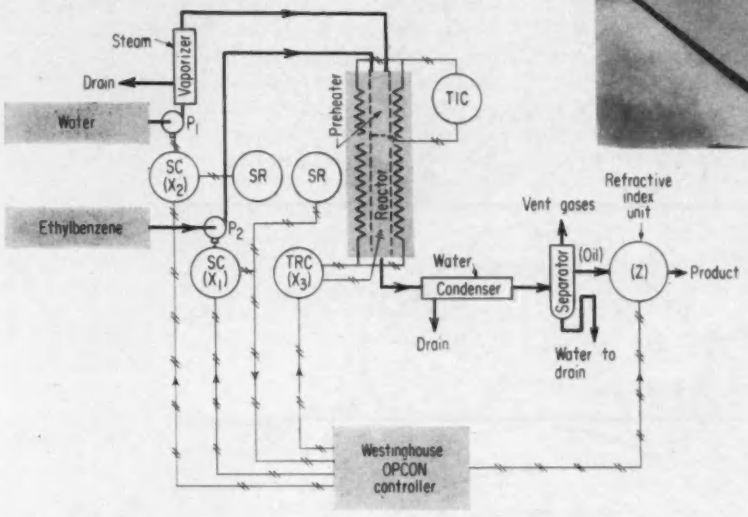


FIG. 3. OPCON and associated recorders and controllers mounted on miniplant control panel.

FIG. 2. The dehydrogenation miniplant and instrumentation used in evaluating OPCON.



THE PLANT AND ITS INSTRUMENTATION

plant) complete with the necessary instrumentation for connecting with the OPCON control. Dow also provided the personnel for installing and operating the process control system. Westinghouse provided the OPCON and its installation and maintenance.

The process and its instrumentation

The process used for this evaluation is the catalytic dehydrogenation of ethylbenzene to styrene, which is part of the process used for the commercial production of styrene. The basic process reaction is:

$$C_6H_5{-}C_2H_5 \xrightarrow[\text{Catalyst}]{\text{Heat}} C_6H_5{-}CH = CH_2 + H_2$$

(ethylbenzene ⟶ styrene + hydrogen)

The reaction is endothermic, the required heat being supplied by superheated steam. The steam also reduces the partial pressure of the reactants, shifting the equilibrium to favor styrene production. In commercial operation, 35 to 40 percent of the entering ethylbenzene is converted per pass, and 90 to 92 percent of the reacted ethylbenzene is converted to styrene. The unreacted ethylbenzene is separated and recycled. Small amounts of benzene, toluene, and higher molecular-weight compounds are formed in the reaction and are separated from the styrene in subsequent steps. In the miniplant the reaction products are not separated, and there is no recycling.

The miniplant, normally used for studying styrene-process catalysts, is designed for continuous operation. Figure 2 shows the miniplant and its control scheme using OPCON. Ethylbenzene and water are fed by positive-displacement syringe pumps which accurately meter small flows. The water is vaporized by a heat exchanger before entering the reactor. The ethylbenzene is vaporized and the steam superheated in the reactor's preheater section. The vapors then pass to the reaction section where the temperature is raised and the conversion to styrene occurs. The vapors from the reactor are condensed and pumped to the separator where the vent gases are released and the oil and water layers separated.

Process instrumentation

The instrumentation of the miniplant, Figure 3, was so arranged that the OPCON control could vary any two of the three primary variables—ethylbenzene flow, water flow, or temperature of the reactor section—affecting the process. The optimizing criterion for initial trials was maximum production.

As far as possible, standard, familiar process instruments and transducers are used to record and control the process parameters and interconnect with the OPCON control. This simulates normal conditions so interconnecting devices are also evaluated.

A Dow-designed refractometer continuously samples the oil stream and records (essentially) the percent conversion to styrene. The refractive-index reading, Z, is transmitted to OPCON by a ten-turn potentiometer and is multiplied by the ethylbenzene

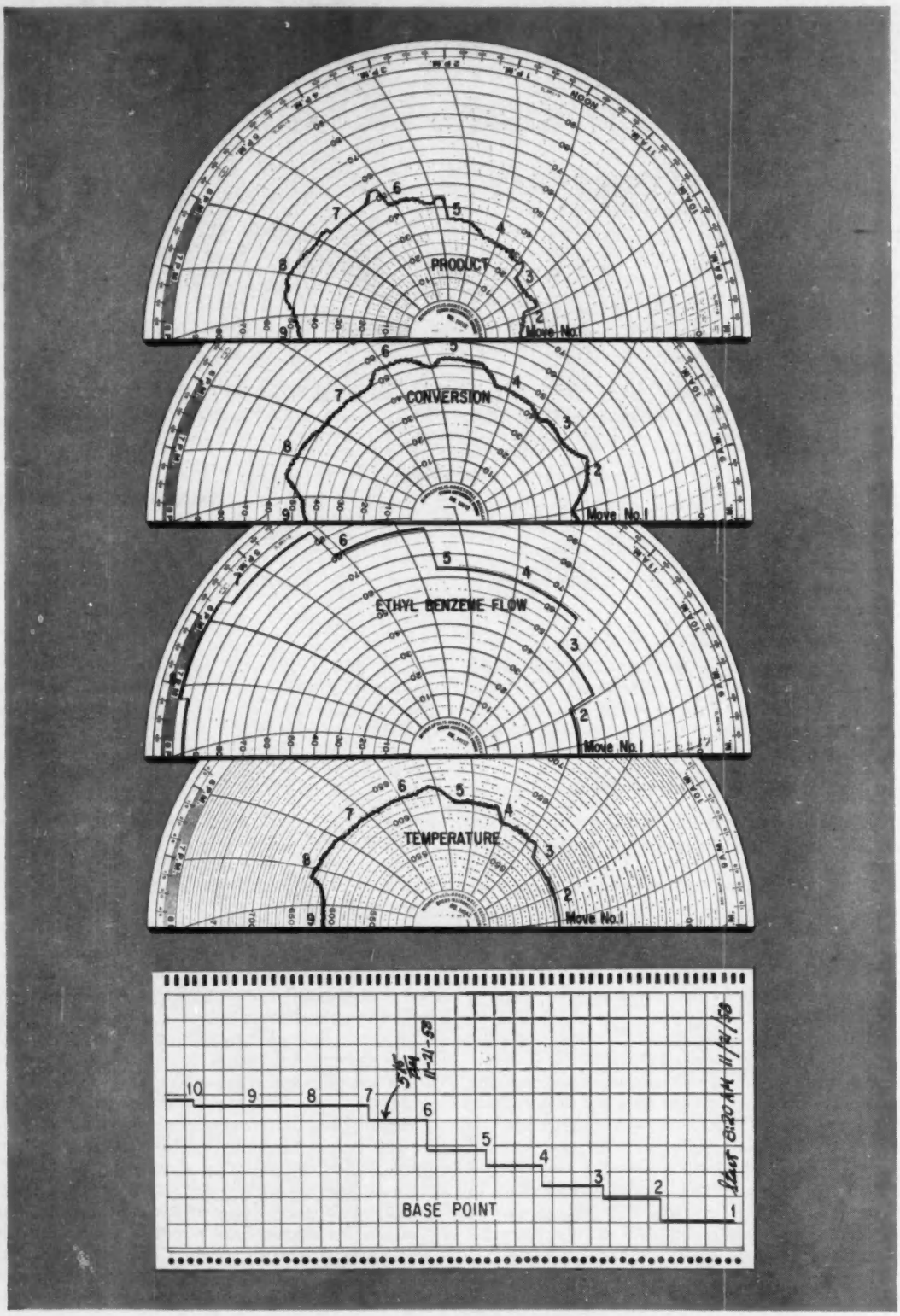


FIG. 4. Actual chart records of the start of an optimizing run, retouched here to emphasize detail about optimizing operation and effect of process dynamics.

flow X_1 to determine maximum production, the chosen optimum criterion, ZX_1.

The flows are determined by speed controllers, SC, on the pumps adjusted by pneumatic cylinders which can be set manually with air loading stations, or automatically by OPCON through electric-to-pneumatic converters. Electrical signals from the speed controllers are transmitted to round-chart potentiometer recorders. The electrical signal from the ethylbenzene speed controller is transmitted also to OPCON for multiplication with percent conversion; and the resulting signal is continuously recorded.

The reactor's preheat-zone temperature is set manually and controlled by a thermocouple pyrometer adjusting the electric heaters. The reaction-zone temperature is controlled by a thermocouple, attached to the jacket wall, connected to a potentiometric round-chart controller with pneumatic output that controls the electric heaters through a cylinder-operated autotransformer. This controller can be set manually or automatically through an electric-to-pneumatic converter coupled to the OPCON unit.

Limit switches on both flow recorders, on the percent-conversion recorder, and on the temperature recorder are all connected to OPCON to signal when a process limit is reached.

What the OPCON evaluation revealed

The OPCON control successfully operated the miniplant using maximum production as an optimum criterion. All combinations of the three input variables were controlled, two at a time. In addition, two input variables were controlled in a set ratio, so that all three input variables were adjusted by the two outputs of the OPCON unit.

The conditions on the miniplant were varied to obtain a good evaluation of the OPCON control. Depending on the equilibrium time for the particular conditions being used, the waiting time between moves was set between 45 and 150 minutes for various runs. The optimizing runs usually lasted three to five days, but some were made for as long as three weeks to see how well the unit held the process at its optimum condition. During these longer runs, upsets were manually introduced to determine the effect of rapid shifts in the optimum operating point.

The actual recorder charts in Figure 4 show the first eight moves of a run where ethylbenzene flow and temperature were the input variables. (Water flow is maintained constant.) The base point recorder shows how production criterion kept rising in value as the OPCON control experimented with the process. This being the start of a run, OPCON generated rather large move sizes. When moves reduce to their smallest size, the process is considered to have reached its optimum. On some runs a small move of approximately one percent was used, so that the process disturbance was very slight as it kept moving around the optimum. If the optimum point started drifting faster than OPCON could keep up with it, OPCON shifted to its next larger move size.

Note that the dynamic properties of the miniplant appear in the recorded responses of the controlled variables to set-point changes generated by OPCON. The ethylbenzene flow-control loop has a small time constant, so it responds almost immediately to a set-point change. Temperature and conversion (and hence production rate) evidence both a larger time constant and a dead time.

Figure 5 shows another, but longer, optimizing run. In this case the set-point signals for temperature and ethylbenzene flow are plotted on linear

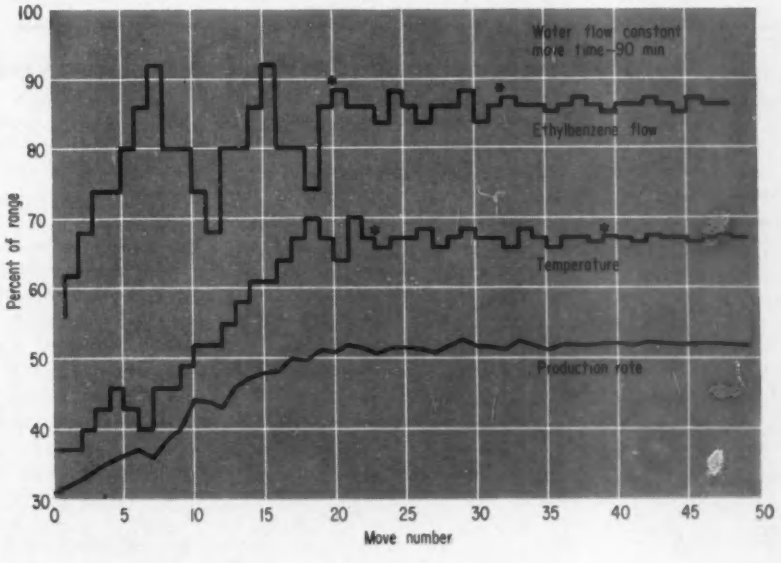


FIG. 5. Another optimizing run, this time plotting OPCON outputs, or setpoint signals to controllers, and their effect on production rate.

coordinate paper to simplify interpretation of how OPCON changes these variables to reach a process optimum. The plot indicates how ethylbenzene flow and temperature are increased, bringing production rate to its maximum. The move size is automatically reduced when OPCON senses that it is getting decreases in production rate in every move direction, thus indicating the process is in the region of optimum operation. These move reductions (noted by asterisks) are at moves 20 and 32 for ethylbenzene flow and at moves 23 and 38 for temperature. At the optimum condition, the production rate came to a fairly steady condition while the two input variables were continually searching about their optimum levels to follow any changes in the process conditions. This plot would be typical of an experimental installation where it was desired to establish unknown optimum conditions. In an operating plant, however, the input variables would be set at the start as near as possible to the optimum conditions, and then OPCON would experiment in small move sizes to find and hold the optimum level.

As might be expected, various troubles were encountered in installing and operating this first OPCON control. However, excluding the initial trials, there has been relatively little downtime. Most downtime was due to making and evaluating OPCON circuit revisions or to making changes in the process equipment. The troubles that occurred in the OPCON unit were in the peripheral equipment, not in the logic circuits which use static components. Most problem areas have been corrected and have been redesigned for subsequent units.

Some troubles arose in the process interconnections, primarily in not being able to accurately move the process variables in very small increments or to accurately measure the subsequent change in the optimum criteria without introducing excessive process and instrument noise. The OPCON is able to handle random noise through the use of various averaging schemes in measuring the optimum criteria. It is desirable, however, to reduce this noise to a minimum level, so that the OPCON control can experiment in very small move sizes.

Additional process runs are still being made using maximum production as the optimizing criterion, although Westinghouse is building an analog computer unit for this installation which will calculate a more realistic optimizing criterion for this process. This new criterion will take into account the value of the materials being processed, the process utilities, product purification, and by-products. With this criterion the process will be held at its maximum economic level under all operating conditions.

In a miniplant or pilot plant, OPCON could be used advantageously to quickly find maximum and minimum process operating conditions, as well as record the results of all its experiments between these conditions. Different strategies could be employed and provision made to gather complete data around specified operating points.

The most important economic application is in the field. Here it should prove quite valuable in optimizing specific operating plant units where more complex computer installations are impractical.

While many advantages can accrue from using OPCON or a similar optimizing technique, Dow's evaluation emphasizes five important prerequisites (see below) for a successful installation.

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FIVE POINTS TO LOOK FOR WHEN APPLYING OPCON

1. An output measurement must be made that can be related to the desired optimum criteria, either directly or through subsequent calculations. (This measurement could be discontinuous in most applications.) In many cases suitable process analyzers have not been developed to measure the desired product criteria, making this a limiting factor.
2. It must be possible to vary all primary input variables that affect the measured output. The present OPCON control varies two inputs. Theoretically there is no limit to the number that could be varied; however, a practical limit is reached fairly quickly due to the increased complexity and cost of the OPCON equipment.
3. The time lag between making moves with the OPCON control must be less than the time variation of other process disturbances. Otherwise OPCON will not know whether a process change is due to its experiment or to some other disturbance.
4. The optimum criterion must be chosen so that it is normally within the process limits in a plant application. Otherwise there would be no point in installing this type of control.
5. Such uncontrolled process variables as feed-flow or composition changes or variable economic conditions would have to be present to warrant permanent installation of an optimizing control. However, a temporary installation to find the optimum operating point may be justified on any type of process.

How to Specify Resolution for Potentiometer Servos

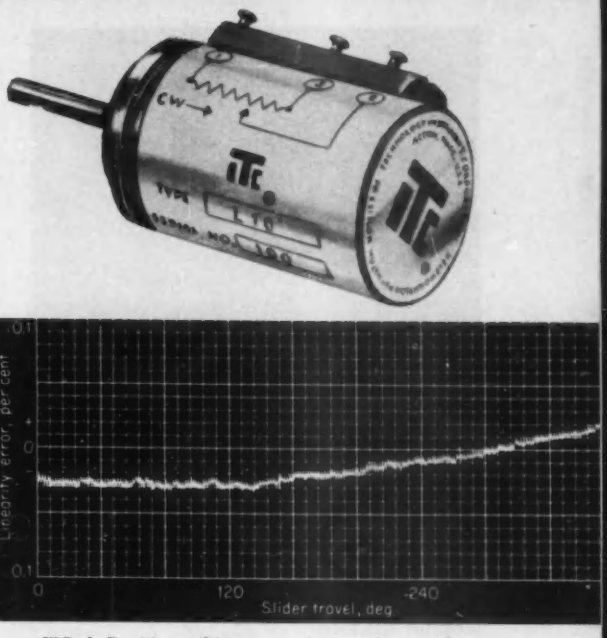

FIG. 1. Precision multiturn potentiometer shown with an actual recording of its resolution characteristic.

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Technology Instrument Corp.

THE GIST: In potentiometer feedback systems the resolution steps, inherent in even the most accurate wire-wound potentiometers, often pose a rather serious stability problem. In this article the author uses an extension of the describing function technique to analyze the relationship between resolution and system performance and derives some stability equations of practical significance to the systems designer.

Precision potentiometers find wide use in feedback control systems because of their accuracy, low cost, and flexibility. Through concentrated design effort, the earlier problem of contact reliability has been minimized. However the finite resolution of wire-wound potentiometers remains a barrier to further extension of performance limits.

While certain film-type potentiometers offer essentially infinite resolution, their linearity and temperature stability preclude their use in systems demanding extreme accuracy. For this reason the following discussion deals only with the more accurate wire-wound potentiometers and the effects produced by their finite resolution.

The ultimate precision of any wire-wound potentiometer is limited by the fineness of its wire, and since wear reduces reliability, manufacturers hesitate to use wire sizes smaller than about one mil. In a single-turn potentiometer, then, resolution cannot exceed about one part in two thousand per inch of diameter. Where space requirements impose limits on the diameter, resolution can be greatly improved by means of multiturn potentiometers. This type of construction extends resolution limits by a factor roughly proportional to the total angular travel. Figure 1 shows a typical 10-turn precision potentiometer and a recording of its resolution characteristic through one complete turn. Although this particular model has an outside diameter of only $\frac{7}{8}$ in., its maximum linearity error (not shown here) is less than 0.03 percent.

In spite of these characteristics, the servo designer must still understand the effects which resolution can impose on the performance of a complete system. Only when this relationship is known can resolution be specified in a straightforward scientific manner.

Figure 2 illustrates the difference between an ideal resolution characteristic and that which is encountered in actual practice. Curve A represents the ideal case in which the slider contacts only one turn of the wire at any time. In practice, however, the slider is designed to simultaneously contact more than one wire. Curve B shows this condition. Whenever the slider contacts two turns of the wire it short-circuits one complete turn. This produces an intermediate voltage resolution step which varies in magnitude from $1/n^2$ near the ends of the winding to $1/2n$ at its center. But since these steps have little effect on the resolution near the extreme ends of the winding, and since only the worst condition should

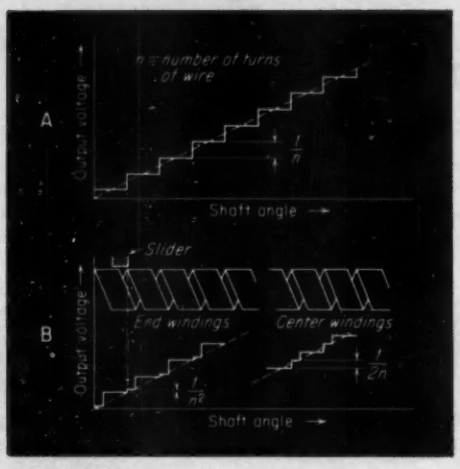


FIG. 2. Resolution characteristic produced when (A), slider contacts only one wire at a time, and (B) when slider contacts more than one wire simultaneously.

be considered, the ideal curve A will suffice for purposes of analysis.

Unfortunately, because of their nonlinear character, resolution problems cannot be analyzed by any of the more common design techniques. On the following pages, then, approximate techniques will be used, results will be reduced to a practical form, and rules will be developed to enable the designer to specify with some certainty the resolution required of potentiometers in any given system. Analysis will include the additional nonlinearity of static friction, without which the resolution problem would be meaningless. The approach here will be an extension of the describing function technique.

The effect of potentiometer resolution on system accuracy is obvious, since resolution steps represent deviations from the linear characteristic. Less obvious, however, is the effect of resolution on system stability. Frequently this effect can only be eliminated by a considerable reduction in sensitivity.

Factors normally at work to limit the sensitivity of a servo to small signals include: 1) the slot effect, or cogging in the servomotor, normally less than three percent of rated control field voltage; 2) motor, gear train, and load stiction and friction; 3) reduced amplifier sensitivity due to electrical noise.

Each of these acts in a different way, friction being the most effective. Where these factors fail to produce a sufficient reduction in sensitivity, friction or damping may be increased or gain reduced.

Approaching the problem

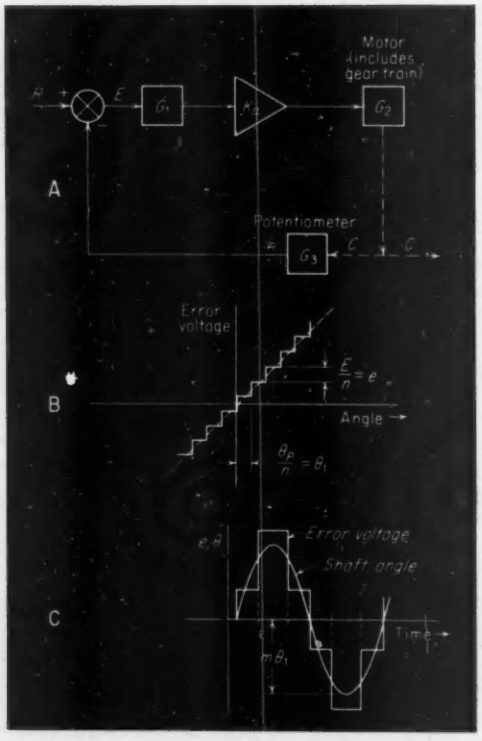
The describing function of a nonlinear device represents the vector ratio of the fundamental component of its output to its sinusoidal input and is determined as a function of input amplitude. The intersection of the negative reciprocal of the describing function and the open-loop transfer function of the servo on an *L*-plane plot defines a point of instability. Stabilizing a servo means avoiding this intersection.

To limit the problem of determining the describing function of the wire-wound potentiometer, consider the application of this describing function to the analysis of the servo shown in Figure 3A. This is a typical potentiometer servo, and results of its analysis will be widely applicable.

Usually, because of the resolution steps, the match between input voltage and potentiometer voltage will not be exact. If gain is sufficient, the potentiometer will oscillate about the required point, covering a range of positions which effectively average out to match the input. In the absence of static friction, no stable condition can exist other than the discrete output values which the potentiometer can generate. Thus, as a rule of thumb: if servo sensitivity exceeds half a step, oscillations *will* occur.

From another point of view, servo gain is *infinite* due to the resolution steps. The worst position stability-wise is when the required voltage is exactly midway between two steps. This position may be assumed for purposes of analysis. Since infinite gain occurs only for very small oscillation amplitudes, resolution oscillations tend to have small amplitudes. As soon as amplitude increases, gain falls. To eliminate these oscillations, a form of damping should be introduced which is infinite for very small amplitudes, and which decreases as the amplitude gets larger. This requirement is easily filled by the application of *static friction*, which has a constant magnitude independent of rotational speed. Since the viscous damping coefficient equals the ratio of damping torque to rotational velocity, static friction, which

FIG. 3. (A) Typical servo with potentiometer feedback; (B) Resolution characteristic showing maximum resolution steps; (C) Input and output waveforms for small amplitude oscillation.



provides a fixed damping torque even at extremely low speeds, effectively yields the required infinite damping coefficient. At higher amplitudes—hence, higher velocities—the effective damping coefficient due to static friction diminishes. Although static friction is ideally suited to potentionmeter servo stabilization, it can also introduce intolerable static inaccuracies.

Potentiometer resolution

On the resolution characteristic, Figure 3B, assume the zero point to be in the center of a resolution step. To determine the describing function, a sinusoidal oscillation of the potentiometer shaft about the reference point is introduced. The number of steps traversed by the input wiper will depend on the magnitude of this oscillation, and Figure 3C shows a typical output waveform for an oscillation of relatively small amplitude. Analysis of this waveform will establish the fundamental Fourier component. An inspection of the figure shows that there will be no phase shift between output and input. Figure 4 shows the nonlinear describing function as a function of oscillation amplitude m.

It is easy to apply the potentiometer describing function to the elementary servomechanism of Figure 3A. The linear servo transfer function has the characteristic shape shown on the polar coordinate diagram of Figure 5. On this same diagram the negative reciprocal of the describing function is plotted on the negative real axis. Since the describing function goes to infinity at zero amplitude, its negative reciprocal enters the origin negatively. Therefore, if the servomechanism transfer function crosses the negative real axis at any point, instability results. (This, however, is simplified theory and subject to limitations described elsewhere.) The transfer function of a second order servo crosses the negative real axis at the origin and, in theory, oscillates at zero amplitude and infinite frequency. In actual practice additional secondary time constants and static friction considerably affect this behavior.

To stabilize the second order servo by conventional damping, gain must be reduced or the shape of the Nyquist locus changed to avoid the entire negative real axis. Thus, in the limiting condition, static friction, which sharply affects the locus at small amplitudes, can provide the stabilization.

Static friction

For very small amplitudes, the damping introduced by static friction approaches infinity. It is possible to determine the equivalent viscous friction corresponding to static friction for the condition of sinusoidal oscillation.

Assume an angular sinusoidal oscillation of a shaft having coulomb friction to ground. On the basis of equivalent energy concepts, the effective viscous friction may readily be found. Let θ equal $\theta_m \sin \omega t$,

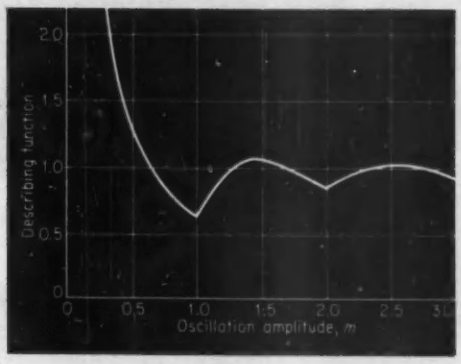


FIG. 4. Effect of oscillation amplitude on potentiometer describing function.

where θ_m is the maximum oscillation amplitude, ω, the angular frequency, and θ, the instantaneous shaft position. The instantaneous angular velocity, $\dot{\theta}$, is determined by differentiation:

$$\dot{\theta} = \omega\theta_m \cos \omega t = \omega_m \cos \omega t$$

Figure 6 shows the relationship between instantaneous static friction and velocity. Power dissipated as friction at any instant is the product of frictional torque and angular velocity:

$$P = \omega F = \omega_m F \cos \omega t$$

This power is always positive due to the reversals in polarity of F with velocity reversals. The average power is therefore:

$$P_{avg} = \omega_m F\,(2/\pi)$$

For viscous friction the power variation follows the instantaneous pattern of Figure 6. Since viscous friction is proportional to angular velocity, it may be expressed as $D\omega = D\omega_m \cos \omega_t$

Average power in this case is $P_{avg} = \frac{1}{2} D\omega_m^2$

The viscous friction may be assumed equivalent to the coulomb friction when the average powers are equal: $P_{avg} = \omega_m F\,(2/\pi) = \frac{1}{2} D_{eq}\omega_m^2$

Solving for D_{eq}, the coefficient of equivalent viscous friction, yields

$$D_{eq} = \frac{4F}{\omega\theta_m\pi} \qquad (1)$$

This may be put on a dimensionless basis by letting θ_m equal $m\theta_1$, where θ_1 is the angle per resolution step, and m is the peak amplitude in terms of resolution steps; and letting ω equal u/T_m where u is a dimensionless frequency, and T_m is an arbitrary time constant, most conveniently the principal motor time constant. Under these conditions Equation 1 becomes

$$D_{eq} = \frac{4FT_m}{\pi u m\theta_1} \qquad (2)$$

All angles and torques are measured at the motor shaft.

Servo analysis

Consider once more the system of Figure 3A. Its

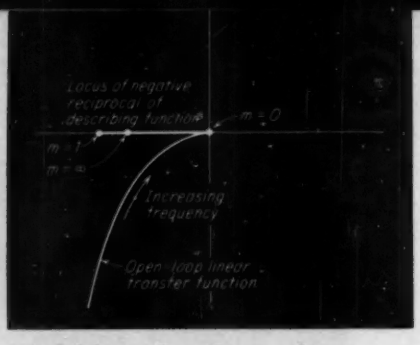


FIG. 5. **Polar coordinate diagram used to determine unstable operating point.**

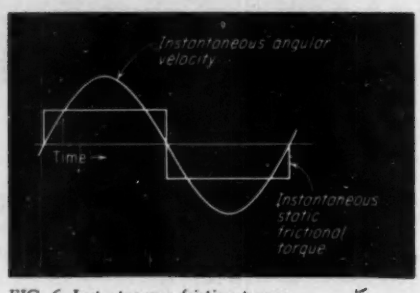


FIG. 6. **Instantaneous friction torque variation with angular velocity**

open-loop transfer function is as follows:

$$G = \frac{G_o K_a K_v R K_p(-1)}{s(1 + sT_m)} \tag{3}$$

By letting (K_a K_v R K_p) equal K_{vo}, i.e., the velocity constant of the entire loop, Equation 3 becomes:

$$G = -\frac{G_o K_{vo} T_m}{sT_m(1 + sT_m)} \tag{4}$$

Thus far the approach of setting up an open-loop transfer function has been based upon the linear characteristics. Assume now that coulomb friction is added to the servomotor. The point of addition does not matter, since friction at any point may be replaced by an equivalent value at the motor shaft. As noted earlier, coulomb friction will behave under a specific amplitude of sinusoidal operation like an equivalent linear viscous friction. And, like viscous friction, it will have the double effect of reducing the velocity constant, K_{vo}, and the motor time constant, T_m. Since viscous damping appears as a dividing factor in both of these functions, both will be reduced in the same proportion. When the reduction factor, x, is introduced, the open-loop transfer function for steady-state sinusoidal oscillations is

$$G = \frac{-G_o K_{vo} x(T_m x)}{j\omega T_m(x)(1 + j\omega T_m x)}$$

This, too, can be reduced to dimensionless form by letting

$$j\omega T_m = ju \quad \text{and} \quad K_{vo} T_m = K$$

Then

$$G = \frac{-G_o K x}{ju(1 + jux)} \tag{5}$$

For instability this expression must equal unity, and may be rewritten in a more convenient form:

$$j\frac{G_o}{u} = \frac{1}{Kx} + \frac{ju}{K} = \frac{1}{K}\left(\frac{1}{x} + ju\right) \tag{6}$$

To derive an expression for the reduction factor x, let D_{tot} equal the total viscous damping in the circuit, i.e., the sum of the actual viscous damping plus the equivalent damping of coulomb friction (Equation 2). This may be expressed as

$$D_{tot} = D + D_{eq}$$

The reduction factor x is then given by the following expression:

$$x = \frac{D}{D + D_{eq}} = \frac{1}{1 + \frac{A}{um}}$$

where A equals $(4\ FT_m)/(\pi D\theta_1)$, a valuable number in that it permits a comparison between servos with various constants. It indicates, for example, that the ratio of coulomb friction to viscous damping is a more important parameter than either alone.

Stability equations

Proceeding with the actual stability analysis, let R and I represent the real and imaginary components (functions of u) in Equation 6. Then,

$$j\frac{G_o}{u} = R + jI \qquad \text{where}$$

$$R = \frac{1}{Kx} \quad \text{and} \quad I = \frac{u}{K}$$

Solving for x, and equating this to the expression derived above yields

$$x = \frac{I}{Ru} = 1\Big/\left(1 + \frac{A}{um}\right)$$

or

$$A = \left(\frac{Ru - I}{I}\right)um \tag{7}$$

The constant K is a nonlinear function of m and may be regarded as the product of a constant multiplier, K_o, which is the equivalent large-signal linear gain of the potentiometer and an amplitude-sensitive component, $f(m)$. Expressed in terms of these components,

$$K = K_o f(m) = \frac{u}{I}$$

or

$$K_o = \frac{u}{If(m)} \tag{8}$$

Equations 7 and 8 represent the key stability equations; a simultaneous solution solves the problem.

In any given problem, the values of R and I and the form of $f(m)$ are known. The conditions of the equations determine the borderline of instability, and although the process may be difficult, the simultaneous solution should yield the specific values of m and u (amplitude and frequency) at which

oscillation occurs for specified friction (A) and gain (K_o). However, although this constitutes a complete solution, it is rather laborious and time consuming. Some physical reasoning will simplify the use of these equations.

Assume that the linear design has been carried out with adequate margins for stability. The combination of K_o and viscous damping, D, will then provide necessary stability. Instability problems occur as a result of the large increases in gain which take place at small amplitudes.

From Figure 4 it is apparent that the amplitude-sensitive component, $f(m)$, exceeds unity (meaning gain amplification from resolution) essentially only for values of m greater than 1. For higher values of m, therefore, the tendency toward instability due to potentiometer resolution is insignificant. Coulomb friction, in its turn, only helps stability for m greater than 1. Thus, by letting $f(m)$ equal c/m, Equation 8 becomes

$$K_o = \frac{um}{cI} \tag{9}$$

where c equals $4/(2\pi)$ (From Figure 4). Combining Equations 7 and 9 to eliminate m yields

$$K_o = \frac{A}{c(Ru - I)} \tag{10}$$

Since, in a given problem, the constant A is established by static accuracy requirements and a knowledge of the frictional characteristics of the load, the value of K_o is readily determined. For stability, K_o must be determined for the case of a maximum denominator; i.e., the expression $(Ru - I)$ must be a maximum. Solving for the dimensionless frequency, u, under this condition, establishes the critical value of K_o.

Conclusions

The preceding reasoning and mathematical analysis, although approximate, provide valuable insight into the mechanism of resolution oscillations and the effect of static friction in curtailing such oscillations.

In summary, the static or coulomb friction is defined in terms of the dimensionless parameter

$$A = \frac{4FT_m}{\pi D\theta_1}$$

where F is the static friction; T_m, the motor time constant; D, the linear viscous damping; and θ_1, the angle per resolution step. This term determines the nonlinearity factor, $x>1$, by which the servo velocity constant and motor time constant are multiplied to show the effects of static friction.

If $(R + jI)$ represents the open-loop transfer function (aside from the transfer function of the servomotor and nonlinear elements), the tendency to resolution instability will be measured by $(Ru - I)$, where u is the dimensionless frequency based on the assumption that the linear motor time constant has the value of unity.

For large amplitude oscillations corresponding to the linear condition, gain equals I/R when u equals I/R. For small amplitude, nonlinear oscillations, gain may be expressed as

$$K_o = \frac{A}{c(Ru - I)} = \frac{(2FT_m)/(\theta_1 D)}{(Ru - I)}$$

when $c = 4/(2\pi)$.

Because of the nature of the describing function for resolution, the apparent gain increases appreciably only for oscillation amplitudes less than about one-half of a resolution step. If linear stability requirements are observed, there is little likelihood of oscillations of larger amplitude than this.

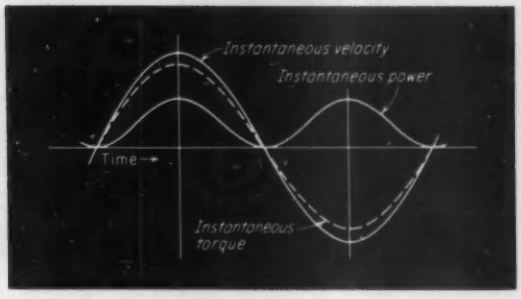


FIG. 7. Instantaneous power, torque, and angular velocity in a system with viscous friction.

Static friction error, when gain is set at the critical value for small nonlinear oscillations, is:

$$E_{static} = \frac{\theta}{2}(Ru - I)_{max}$$

This error, then, is proportional to half the resolution step and the maximum amplitude of $(Ru - I)$.

The servo velocity constant, at the marginal stability condition, is expressed as

$$K_{vo} = \frac{K_o}{T_m},$$

and the stiffness, a function of the velocity constant may be written as

$$K = K_{vo}D$$

From another point of view, examine the system behavior when static friction is such that the torque of one resolution step is inadequate to drive the servo. During the course of one oscillation, the servomechanism will reach a zero velocity condition at the peak amplitude. Output of a damping tachometer at this position will be zero. If the circuit transients initiated by the potentiometer switching are sufficiently decayed, there will be an equilibrium condition and oscillations will cease. In simple servomechanisms, therefore, oscillatory tendencies introduced by resolution steps may be nullified by application of static friction of, say, several times the value corresponding to one half a step. In itself, stiction is a decided asset, in contrast to the steady static or coulomb friction.

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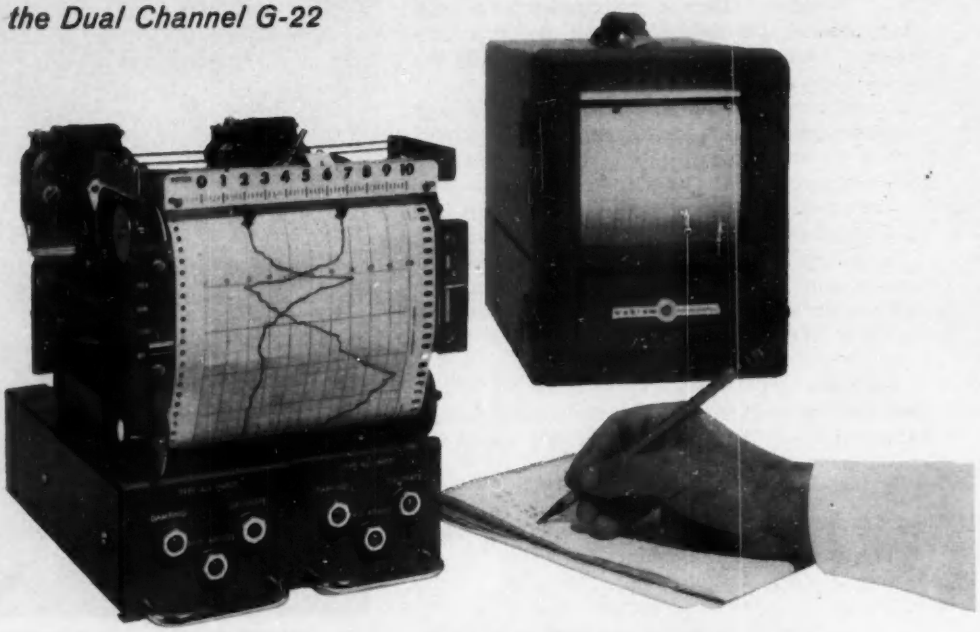

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New Uses of
Static Magnetic Components In Protective Circuits

Studying magnetic amplifier circuits that protect aircraft electrical systems, the control engineer can draw industrial analogies. Such circuitry boasts exact power amplification and accurate predictable time delay. And it lends itself to improved reliability, increased accuracy and life, and decreased maintenance. Here is a discussion of two magnetic amplifier circuits—one for undervoltage protection, the other for overvoltage.

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Because magnetic amplifiers provide an exact method of obtaining power amplification, it is possible to operate voltage comparison circuits at a low power level, amplify the error signal, and operate a standard reliable relay. The relay is then applied only as a power switching element. With the limited performance demanded of it, it is less sensitive to adverse environmental conditions.

Magnetic amplifier circuits also provide an accurate means of producing a predictable time delay. By using the magnetic properties of the core, fixed as well as inverse time-delay can be obtained.

From some applications of magnetic amplifier circuits in aircraft protective systems, industrial analogies may be drawn. Many of the techniques developed by the aircraft industry can be translated into industrial applications.

For example, the increasing dependence of the airplane upon its electrical system for proper operation of the numerous critical loads has made it necessary to design protective equipment that will prevent the destruction of these loads, and the destruction of the electrical system itself, while maintaining electrical power during various system transients of a nondestructive nature.

The majority of protective devices used in past aircraft electrical protective systems depended upon the calibrated operation of relays. The relay functioned as an accurate sensing device as well as a power switching element. In such applications, at rated system voltage and frequency, the coil voltage was either slightly below that voltage necessary to pick up the relay, or slightly above the dropout voltage. The equipment could detect frequency and voltage changes from 5 to 15 percent of rated under this condition. And as a result, these protective devices were sensitive to acceleration, shock, and vibration; but their exact operating points were rather unpredictable. To improve performance, vibration isolators or shock mounts have been used in many applications.

The reliability and accuracy of the protective equipment can be considerably improved by the use of static magnetic components. Since magnetic amplifiers can provide reliable power amplification, the sensing circuit can be operated at low power levels, while the relay is operated at relatively high power levels. The amplifiers can be designed in such a way that they supply full voltage or nearly zero voltage to the coil of the relay. This type of application allows the use of power-type relays inherently more resistant to shock, vibration, and acceleration forces normally found in airborne applications.

This approach has been applied in two aircraft protective circuits: the individual phase undervoltage protection and highest phase sensing overvoltage protection with inverse time delay.

Protecting against undervoltage

Individual phase undervoltage protection guards load equipment against sustained undervoltage caused by:

1. Loss or reduction of excitation
2. Open generator phase winding or feeder
3. Bus faults or feeder faults not cleared either by protective devices or by burning clear.

Figure 1 illustrates a magnetic-amplifier circuit for

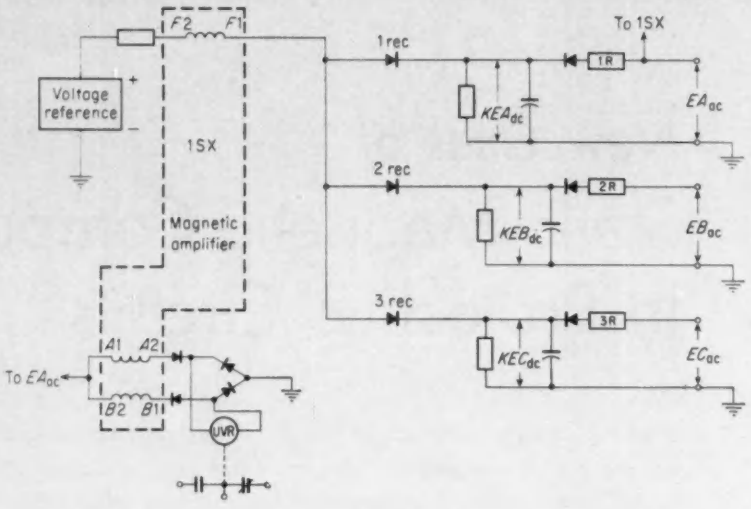


FIG. 1. Magnetic amplifier circuit for undervoltage protection.

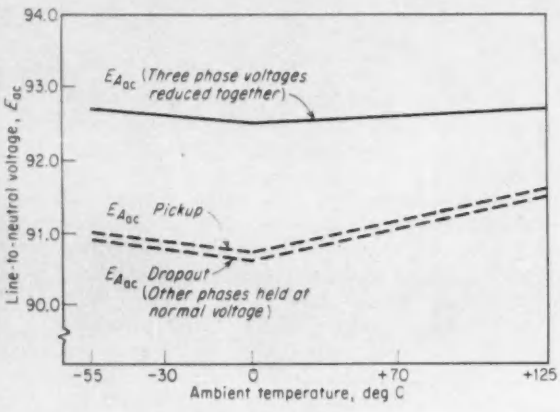


FIG. 2. How temperature affects operation of undervoltage relay used in magnetic protective systems.

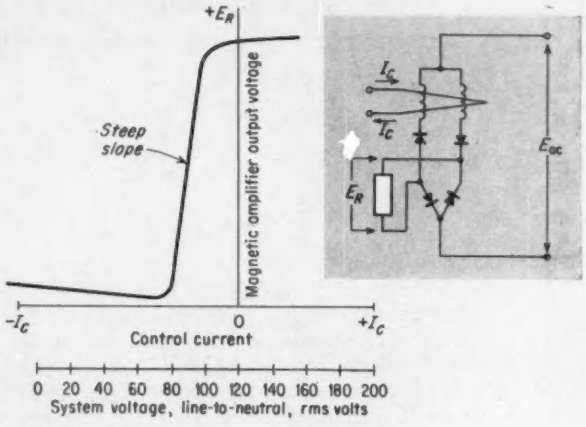


FIG. 3. Steep slope of magnetic amplifier transfer characteristic explains difference between dropout and pickup.

individual phase undervoltage protection. Here's how it works. The voltage on each phase (E_{ac}) is rectified and filtered to produce a voltage (KE_{dc}), which is compared to a reference voltage. With rated voltage on each phase, the dc voltage produced by each sensing network is higher than the reference voltage. The rectifiers 1REC, 2REC, and 3REC are blocking. If, however, any one or all three dc voltages drop below the reference voltage, current flows from the reference through the control winding of the magnetic amplifier (1SX). This causes the magnetic amplifier to reduce its output to a very low value, thereby deenergizing the relay.

As soon as all three dc voltages are equal to or higher than the reference voltage, the magnetic amplifier will increase its output and energize the relay. Settings of the undervoltage relay are changed by varying fixed resistors for 1R, 2R, and 3R.

Figure 2 shows the effect of temperature on the pickup and dropout values of an undervoltage relay circuit. Since the resistance to the flow of control current when a three-phase undervoltage exists is one-third of the resistance for a single-phase undervoltage, the drop-out values for three-phase undervoltages will be higher than for single-phase undervoltages (Figure 2). Note that the differential between pickup and dropout is quite small (difference between dotted curves). The reason can be traced to the steep slope of the magnetic-amplifier transfer characteristic in the operating region.

Overvoltage relay

Overvoltage protection is usually characterized by inverse-time voltage relationships. Large system overvoltages are allowed to exist for only a very brief time; small system overvoltages are allowed to exist for a longer time before the overvoltage protection is energized. Such operation is consistent with the thermal characteristics of the load equipment.

Several types of sensing circuits may be used in

conjunction with the overvoltage circuit; two most widely used are highest phase sensing and average phase sensing. In most present day systems the overvoltage relay senses the average of the three line-to-neutral voltages and trips when this average exceeds a predetermined ultimate trip voltage.

With average phase sensing it is possible for one or two phases to have an overvoltage, with reduced voltage on the other phase or phases, without causing tripping of the overvoltage relay circuit. This condition would allow an overvoltage to exist on some single-phase loads. One way to correct this problem is to use highest-phase sensing, the circuit of which is shown in Figure 4 (shaded). The three line-to-neutral voltages EA_{ac}, EB_{ac}, EC_{ac} are rectified through 1REC, 2REC, 3REC and filtered by capacitor 1C so that the output voltage EO_{dc} is approximately proportional to the highest of the three line-to-neutral voltages.

Overvoltage protection with inverse time delay can be obtained by utilizing the magnetic amplifier as shown in Figure 4 (unshaded). A portion of the dc voltage EO_{dc} approximately proportional to the highest of the three line-to-neutral voltages is compared to the reference voltage. Under rated voltage conditions, the voltage

$$E_{2R} = \left(\frac{2R}{1R + 2R}\right) EO_{dc}$$

is less than the reference voltage and rectifier 1REC is blocking. As the voltage on any one phase or all three phases of the system rises, the voltage (E_{2R}) will finally exceed the reference voltage, causes a voltage to be impressed across control winding F1-F2 on the magnetic amplifier (1SX). The characteristic of the voltage across this winding as a function of line-to-neutral voltage is shown in Figure 5. The exact value of this voltage (E_c) for a particular value of EO_{dc} will depend upon the reference voltage and the values of 1R, 2R, and 3R.

An understanding of how the magnetic amplifier produces a time-delay characteristic may be obtained

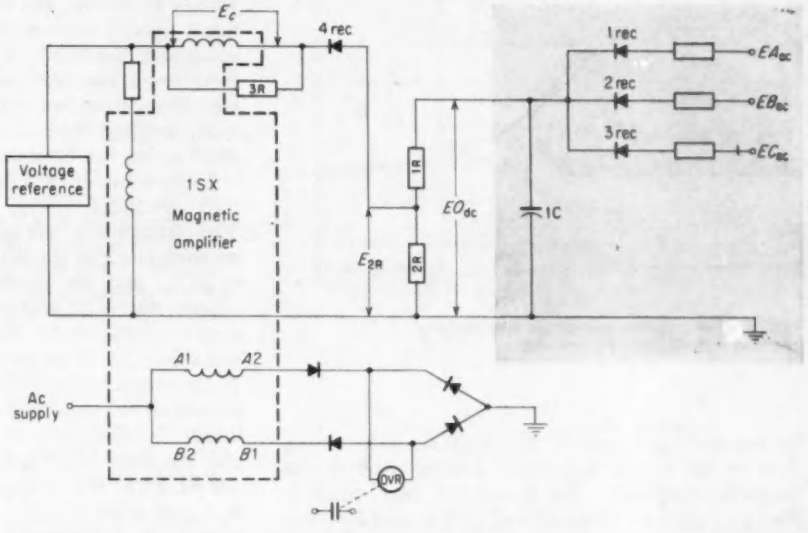


FIG. 4. Magnetic amplifier circuit for overvoltage protection using highest-phase sensing circuit (in shaded box at right).

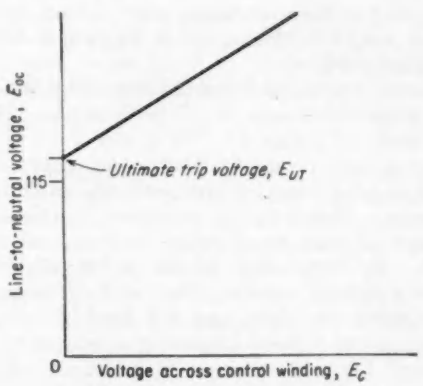


FIG. 5. Plot of voltage across control winding of magnetic amplifier (E_c) vs. line-to-neutral voltage E_{ac}.

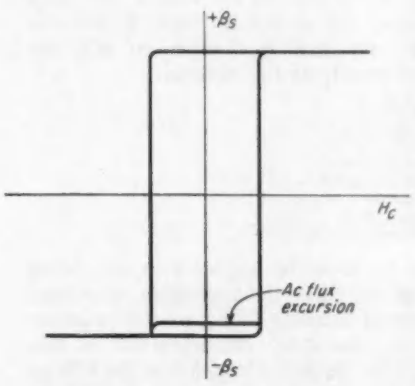


FIG. 6. Hysteresis loop of square-loop core material.

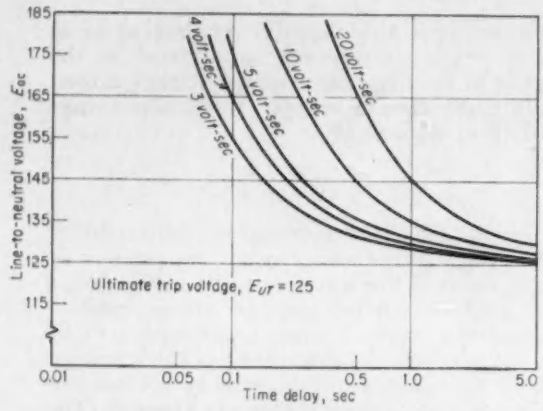


FIG. 7. Family of time-delay curves for overvoltage relays used with magnetic amplifier circuitry.

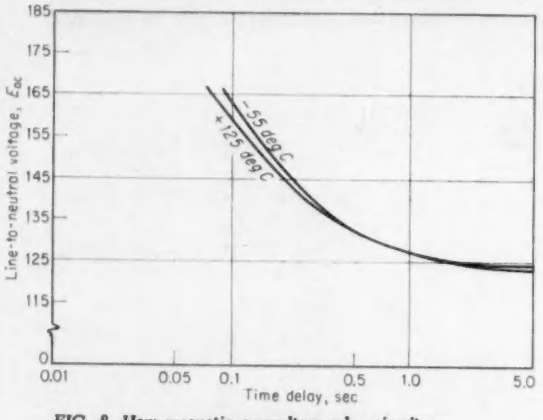


FIG. 8. How magnetic overvoltage relay circuitry performs with changes in temperature.

by considering Figure 6, which shows a hysteresis loop of the square loop core material used in the magnetic amplifier. By means of bias winding *F3-F4* (Figure 4), the core material is initially saturated in the negative direction. By constructing the gate winding *A1-A2* and *B1-B2* with a very large number of turns, the ac flux excursion in the core can be made very small in comparison with the saturation flux density of the material.

where $\beta = \dfrac{E \times 10^8}{4.44 f A_c N_g}$

β = flux density
E = rms voltage
f = frequency
A_c = area of core
N_g = gate winding turns

Its effects can therefore be neglected in calculating the flux change caused by the application of voltage E_C to the control winding *F1-F2* of the magnetic amplifier. The time-delay characteristics of this magnetic amplifier, therefore, depend on the voltage E_C as follows:

$$E = N \frac{d\phi}{dt} \times 10^{-8}$$

$$E_C = N_c A_c \frac{d\beta}{dt} \times 10^{-8}$$

$$\int_0^t E_C \, dt = \frac{N_c A_c}{10^8} \int_{-\beta_s}^{+\beta_s} d\beta$$

$$k_{volt\ sec} = \int_0^t E_C \, dt = \frac{N_c A_c 2\beta_s}{10^8}$$

N_c = Control wdg turns
β_s = Saturation flux density

The final equation shows that for a given magnetic amplifier a definite number of volt-seconds is required to cause the flux density to change from negative to positive saturation or a total excursion of $2\beta_s$. At such time as the cores are saturated in the positive direction, the output voltage of the magnetic amplifier will suddenly increase, causing the relay to be energized.

When the overvoltage is removed, reducing the voltage E_C to zero, the output of the magnetic amplifier is quickly reduced to a very low value, thus deenergizing the relay. The bias winding *F3-F4* will then cause the cores to be reset in the negative saturation direction. Complete resetting is normally accomplished in 1-2 sec, after which the time-delay action can be repeated with excellent accuracy.

Typical values of k required for present-day aircraft excitation systems vary from 3 to 20 volt-sec. The ultimate trip voltage of the relay is determined primarily by the reference voltage, the ratio of E_{ac} to EO_{dc}, and the resistance values of 1R and 2R (Figure 4). The volt-second characteristic is determined primarily by the magnetic amplifier core characteristics, the number of control winding turns on the magnetic amplifier, and the resistance 3R. A family of constant volt-second curves is shown in Figure 7. Once a particular volt-second characteristic has been established for the overvoltage relay (based upon the voltage and time above a predetermined ultimate trip voltage), it is possible by analysis of oscillographic data to determine whether a particular overvoltage transient in the system will cause tripping of the overvoltage relay. If not, the amount of margin remaining before tripping occurs can be determined.

The electrical performance of the overvoltage relay over the temperature range of minus 55 to plus 125 deg C is shown in Figure 8.

The use of magnetic amplifiers in aircraft generator protective systems results in more accurate, predictable operation of the various protective functions. They could be used to advantage in many other fields, too. By eliminating the use of less reliable components such as sensitive relays and electronic tubes, magnetic amplifiers raise the level of component reliability, thereby improving operating reliability and life and reducing maintenance and servicing costs—a key objective of control design.

A Template for Designing Servo Compensators

LT. B. L. POTTS, U. S. Navy
G. J. THALER, U. S. Naval Postgraduate School

The decibel vs phase angle plot is very useful for checking uncompensated servo performance and for checking the effect of compensators. Phase and gain margins are clearly defined. The use of M-contours quickly evaluates M_p and ω_r, and the closed-loop frequency response may be evaluated using M- and N-contours. Compensators are customarily designed with the Bode diagram, but it is a real advantage to have a simple design procedure that may be used directly on the decibel vs phase angle plot. This article presents a simple template for this purpose, explaining its basis in theory and procedures for its practical application.

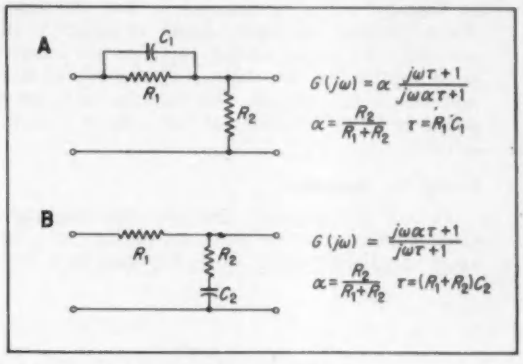


FIG. 1. Simple compensating networks. A—phase lead. B—phase lag.

Development of the template

The template is shown in Figure 3, though for design use it should be made on a sheet of transparent film rather than on paper. The construction and use of this template are based on the following considerations:

A simple phase lead compensator as shown in Figure 1A has the transfer function

$$G_1(j\omega) = \frac{\alpha(j\omega\tau + 1)}{(j\omega\alpha\tau + 1)} \qquad (1)$$

and a simple phase lag compensator as shown in Figure 1B has the transfer function

$$G_2(j\omega) = \frac{j\omega\alpha\tau + 1}{j\omega\tau + 1} \qquad (2)$$

If the attenuation factor α is dropped from Equation 1 (with the understanding that a separate gain adjustment is a necessary step in designing a phase lead compensator), the two equations are reciprocals. Taking logarithms of both sides:

$$20\log_{10}|G_1(j\omega)| = 20\log_{10}|j\omega\tau+1| - 20\log_{10}|j\omega\alpha\tau+1|$$
$$\angle G_1(j\omega) = \tan^{-1}\omega\tau - \tan^{-1}\omega\alpha\tau \qquad (3)$$

$$20\log_{10}|G_2(j\omega)| = 20\log_{10}|j\omega\alpha\tau+1| - 20\log_{10}|j\omega\tau+1|$$
$$\angle G_2(j\omega) = \tan^{-1}\omega\alpha\tau - \tan^{-1}\omega\tau \qquad (4)$$

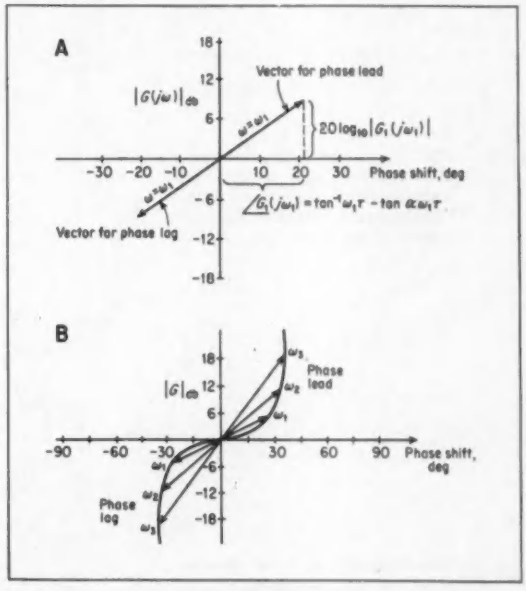


FIG. 2. A—vectors for lead and lag compensators at $\omega=\omega_1$. B—locus of tips of vectors in A as ω is varied, for α and τ constant.

Note that Equations 3 and 4 have identical terms with reversed signs for both magnitude and phase. At any value of ω, each equation represents a vector on the decibel vs phase angle plot as shown on Figure 2A. If α and τ are held fixed and ω is varied, the tips of the vectors describe curves as shown on Figure 2B. These curves have polar symmetry. Therefore one template (Figure 3) serves for both, and a rotation of 180 deg converts a phase lead template to a phase lag template.

For any selected value of α, a curve similar to that on Figure 2B may be drawn. The template is constructed by doing precisely this. The curve is determined by the value of α; the location of a given ω depends on the value of τ, but a given point on the curve corresponds to a fixed value of $\omega\tau$. Since each curve contains points for all values of $\omega\tau$ from zero to infinity, curves of constant $\omega\tau$ can be drawn. These comprise the second family of curves on the template. To permit making points on the compensated transfer function curve, it is advisable to make pinholes in the template (for insertion of a pencil point) at the intersections of the α curves with the $\omega\tau$ curves.

Using the template

To use the template, first plot the uncompensated transfer function curve on decibel vs phase angle coordinates, using scales identical with those used for the template. The gain should be set for the desired steady state performance, and the M-contour for the desired M_p is added. As with Bode diagram techniques the compensator design is a trial and error procedure. The decision to use phase lag or phase lead compensation (or lead-lag compensation or several sections of compensation) is made by inspection, though when using the template it is easy to design one section at a time, using the compensated curve for each section to determine the next.

If a phase lead compensator is to be designed, the template is placed on the curve so that the template origin is in the lower left hand corner. This origin is placed on the uncompensated curve and moved along the curve as desired (the axes of curve plot and template must be kept parallel). Locate the template origin at a point that is to be shifted by the compensator; a good starting point is usually a point that one desires to make tangent to the critical M-contour. With the template origin at this point find a hole in the template that is located suitably with respect to the M-contour. Mark this point on the curve sheet and read from the template the values of α and $\omega\tau$ corresponding to the selected hole; also read the ω of the point under the template origin. These values define α and τ, and the compensation is thus designed if the rest of the compensated locus is satisfactory. The advantage of the template is that it is next used to

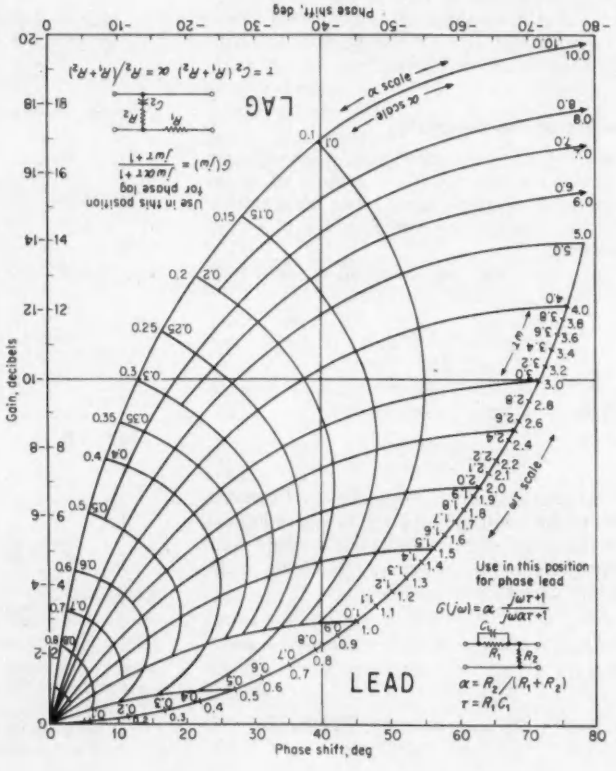
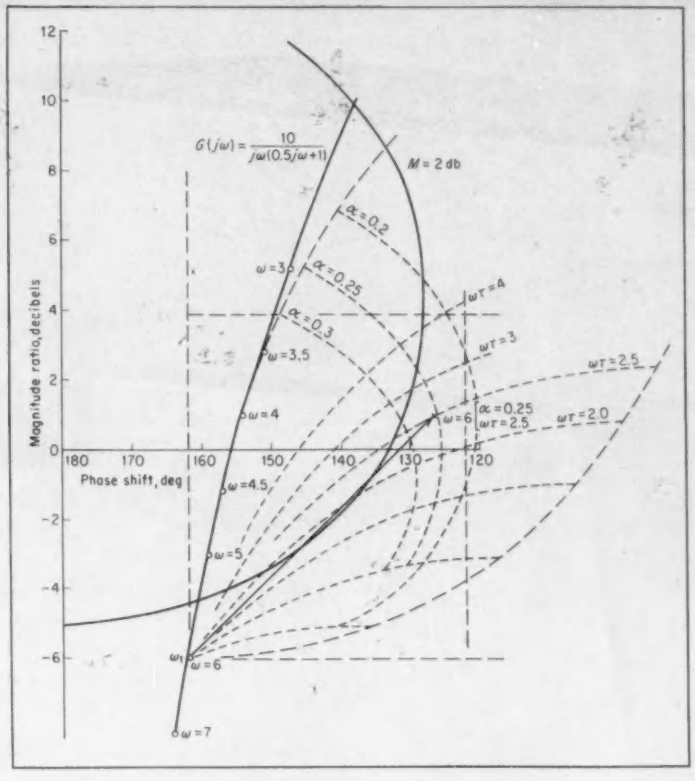


FIG. 3.
Reproduction of transparent template for designing servo compensation directly on the decibel-phase angle plot.

See Shoptalk, p. 6 for special offer on this template.



A

B

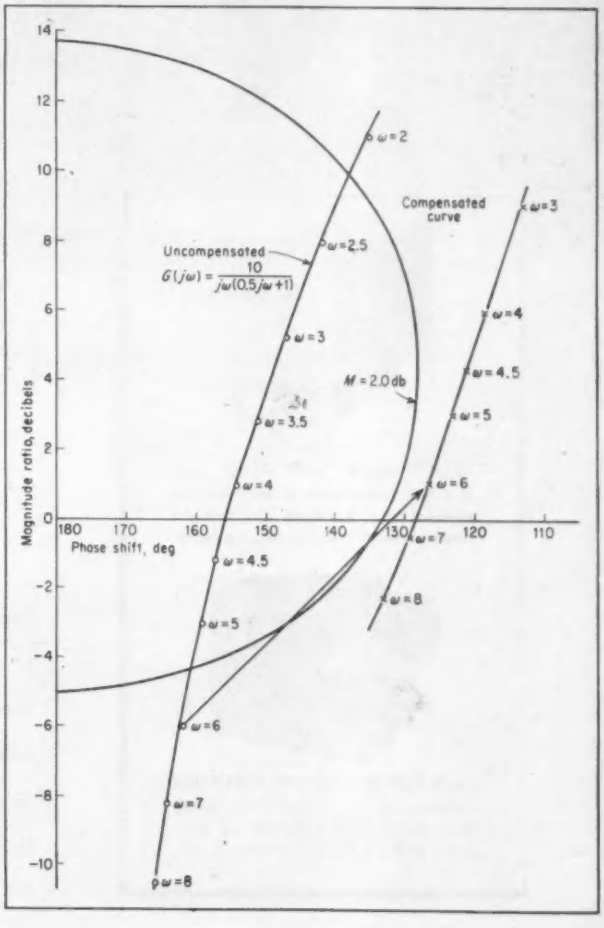


FIG. 4.
A—this one step (see text) is generally all that is necessary to design a compensator using the template. B—check on compensator design.

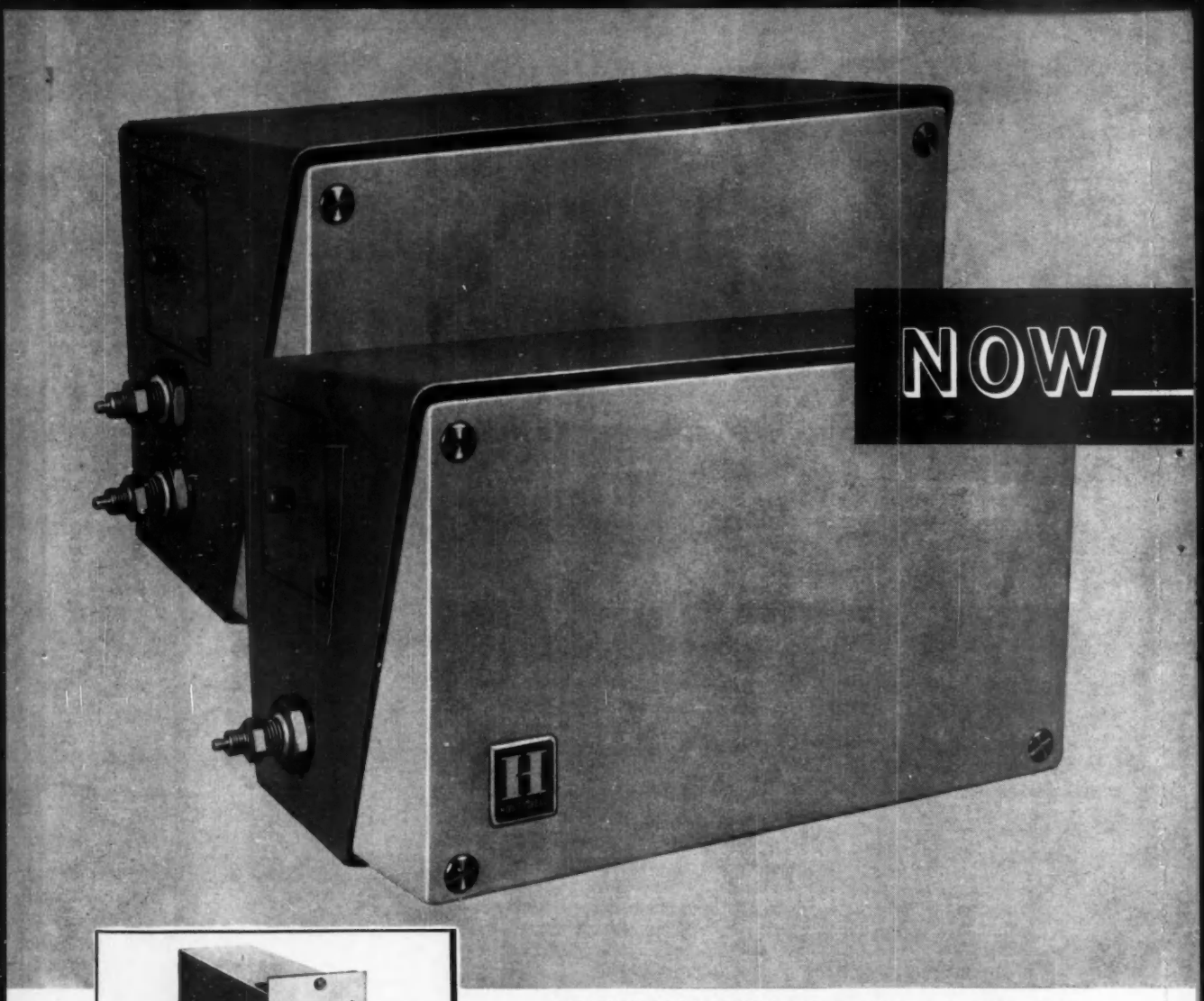
locate rapidly more points on the compensated curve, thus permitting a quick check on the acceptability of the compensated system.

To compute a second compensated point the template origin is moved to another point on the uncompensated curve for which ω is noted and ωτ computed. This new point is shifted by the compensator to the location designated by the intersection of the new ωτ line and the original α line.

Figure 4 shows the procedure for single-section phase lead compensation. On Figure 4A the uncompensated curve, M-contour, and superimposed template are shown. ω_1, at the template origin, is to be moved to approximate tangency with the M-contour, thus α and ωτ are determined as shown. Figure 4B shows the compensated curve also determined with the template.

For phase lag compensation the template is rotated through 180 deg, the origin is still placed on the uncompensated curve, and the procedure is the same as for phase lead compensation design except that the selected point is shifted down and to the left instead of up and to the right.

To design any two-section or multiple-section compensator the procedure is simply repeated. That is, the first section is designed operating on the uncompensated curve, and the second section is designed by operating on the curve resulting from the first section design, etc. When this is done for several cascaded phase lead (or phase lag) sections, the sections may easily be made identical or nonidentical at the designer's option, but the use of an isolating amplifier between sections is required.



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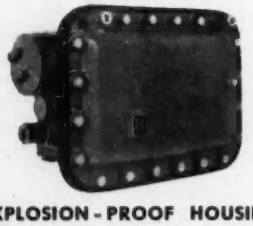

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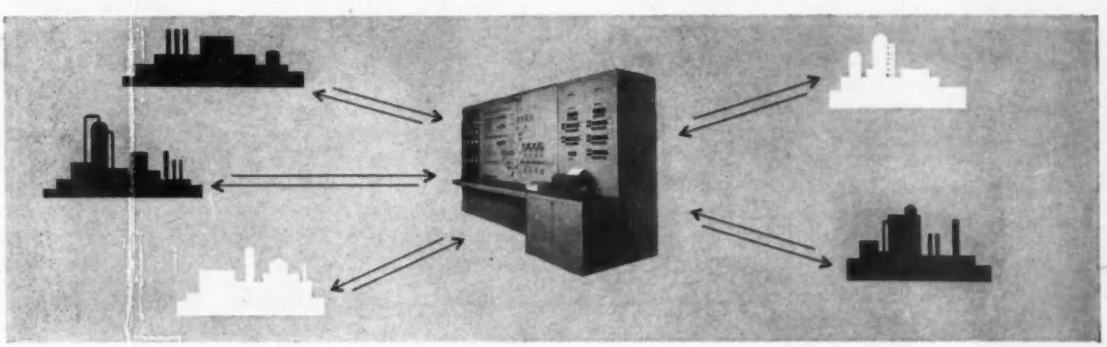
Diagram symbolizes use of transducers in a "wheel-type" plant to convert signals from existing pneumatic instruments to electric signals for data processing or electric control. White silhouettes represent future plants.



CIRCLE 143 ON READER SERVICE CARD

FIG. 1. Electronic teacher puts a pretty student through key punch training at an English office. Unit at left contains main display of four exercise lines on which characters appear. As character stimulus appears, the student pushes what she thinks are proper keys to punch out that character. Below exercise lines is a representation of the keyboard which clues the operator to the proper key. Unit at student's right indicates errors and contains control circuitry.

Electronic Teaching Machine . . .

. . . Drills students, grades their performance and varies their learning pace—automatically.

G. PASK, System Research Ltd.
D. WISEMAN, Solartron Industrial Controls Ltd.

To replace a human instructor, a teaching machine must incorporate functions of inanimate objects—such as a textbook—and the talents of a human being—such as the ability to measure the pupil's performance. It must be able to adapt itself to its student's pace, to devote extra time tutoring him in his weaknesses, and to supply clues to the right answers in the early stages of training. An electronic machine with these capabilities trains keypunch operators in England (Figure 1) and has reduced training time a full 66 percent.

Instead of a textbook, the machine has four exercise lines, each containing 24 lamps that can be lit sequentially. Exercise characters printed on translucent cards are placed over these lines. New work in the course is advanced automatically by switching from one line to the next as the student progresses. Additional four-line cards extend the training program. Electronic circuitry (Figures 2 and 3) takes the place of human teaching skills.

While learning to operate a keypunch, the student sits at a modified keyboard, facing the display unit of the teacher on one side and the control unit on the other. When a lamp lights, the trainee registers his response by depressing a key on the keyboard. (Working with a card punch system with alphabetical coding, the student must depress two keys.)

How well the student progresses depends on two factors: response time and the accuracy of the response. Response rate is the measurement of the time interval between the presentation of the

stimulus and the student's reply. Relay circuitry then determines whether the reply is correct or not.

Because students' learning rates differ, the machine varies the teaching rate, maintaining a pace compatible with the individual pupil's abilities. The electronic teacher does this by varying the time between character stimuli. As the student shows progress, the time interval is shortened. If the pupil makes an error, the rate of character presentation is slowed until the pupil again responds correctly.

To help the beginning student, clues to the correct keys appear on a subsidiary display, just below the exercise lines. The cluing display consists of twelve lamps arranged in the pattern of the keyboard. When the stimulus characters appear in the exercise lines, lamps corresponding to the correct keys glow on the subsidiary display. As the trainee's performance inproves, the illumination of the clues dims until a certain degree of capability is reached—then the clue lights go out. If, after reaching this stage, the pupil makes a mistake, the clues relight, again diminishing in brightness as the student responds correctly to the stimulus characters.

Grading the student is also accomplished automatically. With a single capacitor the machine averages the pupil's performance over the line. When the average exceeds a predetermined value, the machine switches to the next exercise line, which has been designed to be more difficult.

The training machine is built around two key stepping switches, each with eight banks of 25 contacts. Each switch (in Figure 2, S_2) controls

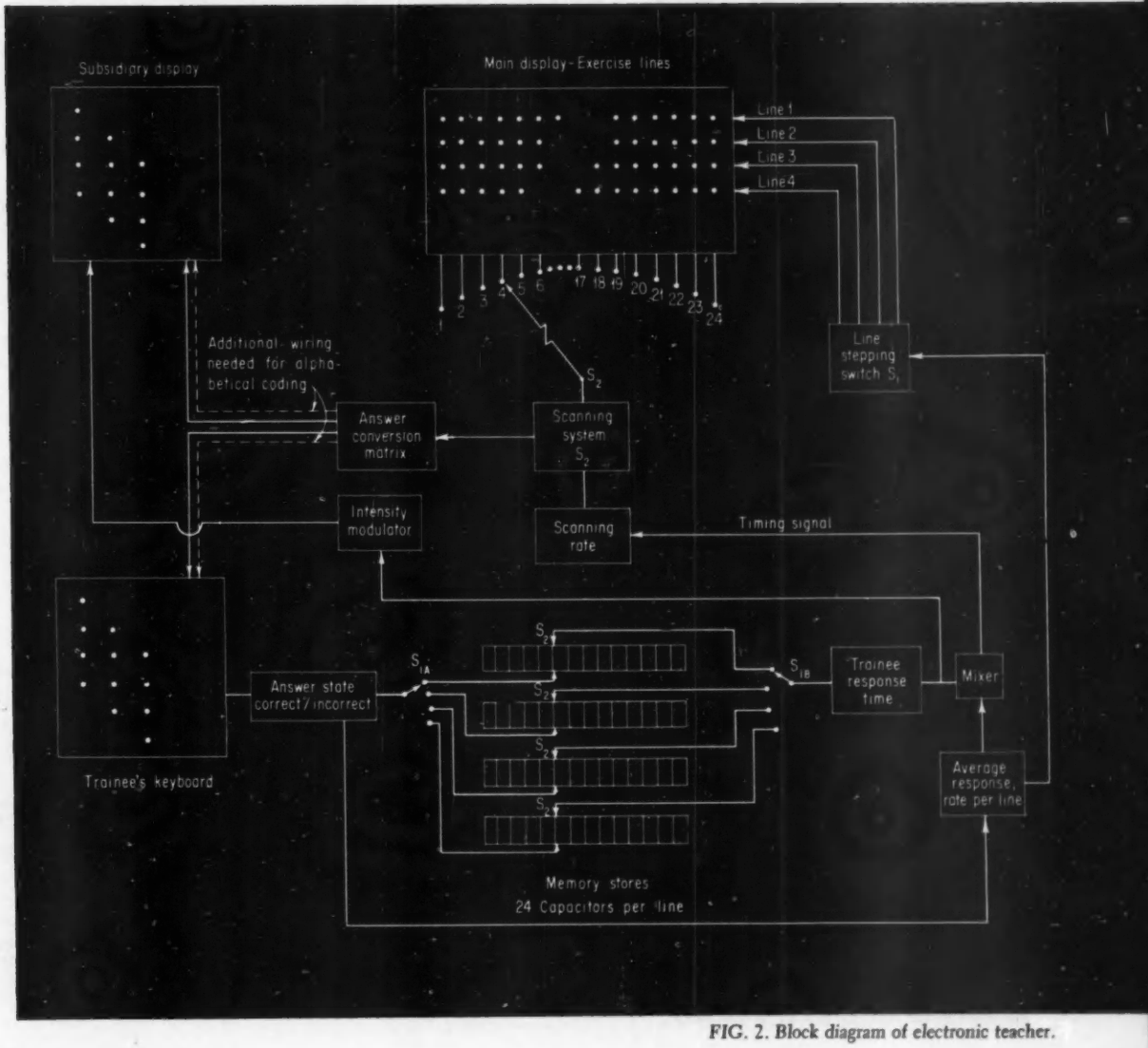


FIG. 2. Block diagram of electronic teacher.

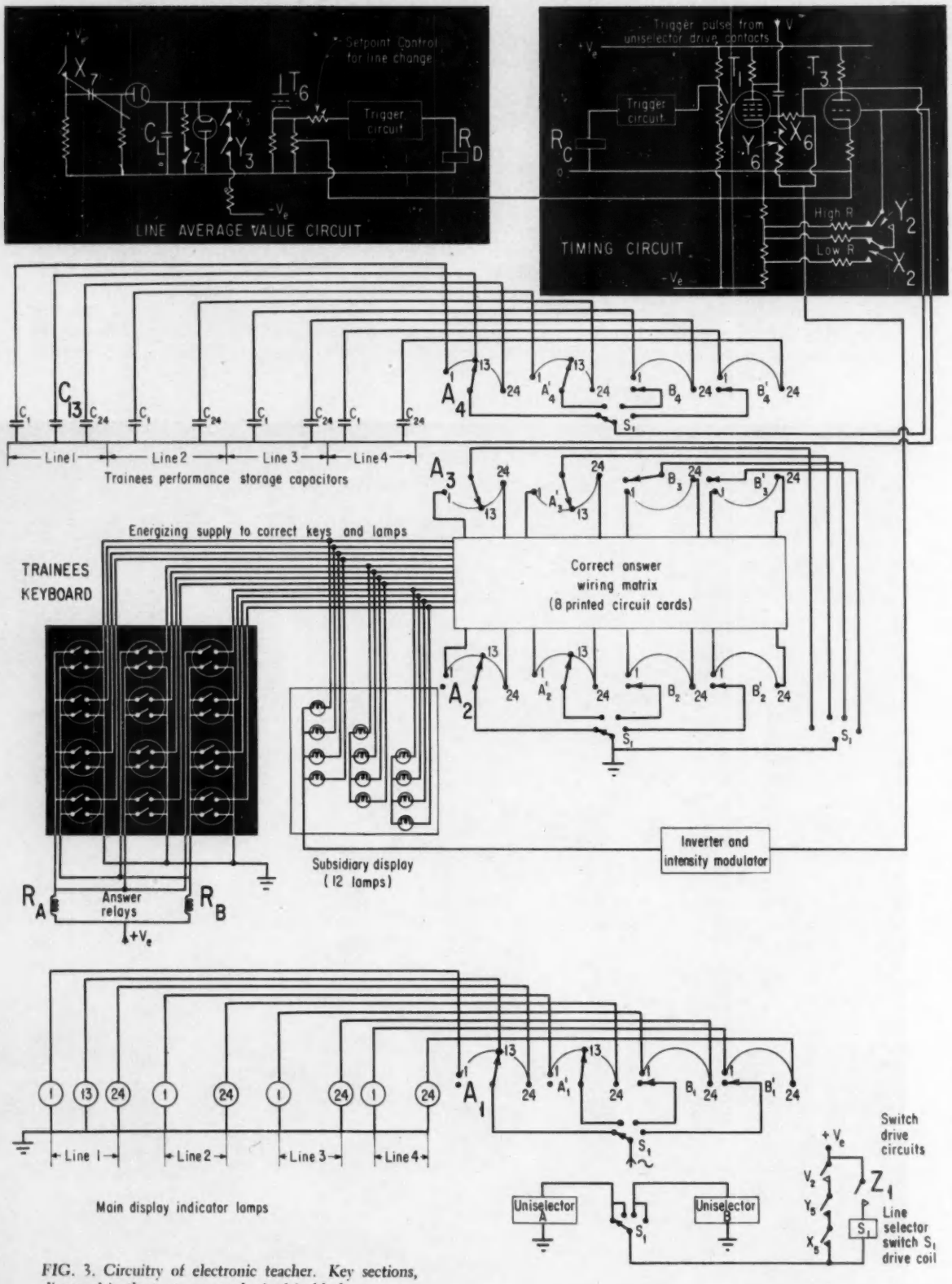


FIG. 3. Circuitry of electronic teacher. Key sections, discussed in the text, are emphasized in black.

two of the four exercise lines. An exercise line requires four banks: one sequentially energizes the 24 exercise lamps; another, through an answer conversion matrix, energizes the correct lamps on the subsidiary keyboard; a third, also through the answer conversion matrix, energizes the correct keys on the keyboard; the fourth (not shown connected) sequentially switches the capacitor storage bank.

The answer-conversion matrix—made up of 3 x 4 in. boards with printed wiring patterns on both sides, at right angles to each other—energizes only the correct answer keys and lamps, corresponding to the indicated character on the exercise line. For rapid changing, rivets inserted through the card provide the appropriate input/output connections for each line. When the translucent exercise card is changed, new matrix cards are inserted, changing the wiring program to that of the new exercise lines. If the code being learned requires the depression of two keys, each exercise line is connected to two cards.

A separate four-position selector switch (in Figure 2, S_1) determines the exercise line and the group of contact banks to be energized. It is stepped by a signal from a circuit which measures the average response rate per line. When the average reaches a predetermined value, the switch steps to the next, more difficult line.

Drilling the student

Figure 3 shows the circuitry of the teaching machine, when the machine has been running on the first exercise line. The character sequencer (A_1) has lit the 13th lamp. Stepping switches A_2 (connecting the answer matrix to the subsidiary display) and A_3 (connecting the answer matrix to the keyboard) are also at the 13th step. And switch A_4, at its 13th step, connects the memory capacitor of that character between the anode and grid of a vacuum tube in a timing circuit.

As switch A_1 illuminates the 13th character, the student depresses a key on the keyboard, which would punch out the character on a keypunch. Each key is fitted with two open contacts connected to answer relays R_A and R_B. Relay R_B is operated by a correct or incorrect key, but only a correct response will close relay R_A.

Grading the student

Here is what happens. When the contacts of the keyboard relays R_A and R_B drop in, charge from the character storage capacitor is applied between the grid and anode of T_3, determining the slope of a sawtooth waveform generated by the phantastron T_1. The waveform acts as a variable delay, then initiates a trigger circuit to close relay R_C, applying a drive pulse to move the stepping switch to its next position, 14. The pupil's response, however, modifies the instantaneous time interval between two successive positions.

Instantaneous value of the time interval depends on the charge on the character storage capacitor C_{13}. A correct response, which has energized relays R_A and R_B, operates contacts X_2 and Y_2, increasing the negative charge on C_{13}; simultaneously, contacts X_6 and Y_6 (in the timing circuit) short out the phantastron discharge path to reduce the delay time. In this way, a correct response reduces the cycle time and increases the charge on the character storage capacitor to maintain a new display rate when the stepping switch again reaches position 13.

Superimposed on this instantaneous time variation is the effect of the pupil's performance over the whole of the line. A line average-value circuit generates this voltage. Correct responses operate contacts X_7, positively charging the line average capacitor C_L. A portion of this voltage maintains the cathode of tube T_3 at the average line performance value. Improved performance, evidenced by correct answers, raises this potential and reduces the mean display time generated by the phantastron over all the characters in the line. An incorrect response discharges the line average capacitor C_L via contacts Y_3, which are connected to a negative supply, slowing the average rate of character presentation.

Changing the clues

To vary the intensity of light in the answer clues, an intensity modulator operates. Here's how it works. The positive output from T_3 passes through an inverter and cathode follower to energize the common side of the subsidiary lamp display. The correct-answer wiring matrix completes the circuit to energize the appropriate lamp. The increasing line average performance raises the voltage in the cathode of T_3, gradually reducing the intensity of all clue lamps until they eventually extinguish. If, at this stage, the pupil makes an error, discharging an individual character storage capacitor, the particular display lamp relights as a result of the potential fall at the T_3 anode, again providing an answer clue.

Advancing the student

When a predetermined average performance on a line has been attained, the stepping switch moves to the next line. To do this, the line average performance voltage is taken from the cathode follower T_6, via a preset potentiometer, to a trigger circuit. Setting of the potentiometer controls the performance value to be reached before the trigger circuit operates to energize relay R_D. Closing of contacts Z_1 steps the line selector switch to the next line, discharges the averaging capacitor, and the training cycle repeats on a new line.

Although this particular machine is designed for training card punch operators using a specific 12-button keyboard, the same principles apply to teaching other keyboard skills such as operating a typewriter or an adding machine. Such complicated operations require displays of groups of letters or numbers, making the problem difficult. A short term memory is needed to store the groups so that each response within the group can be analyzed.

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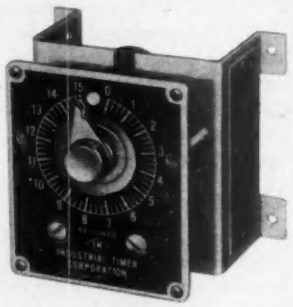

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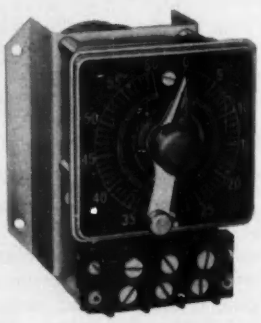

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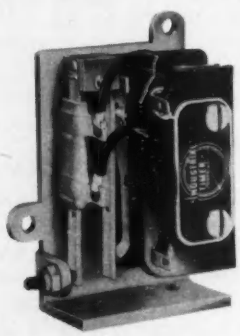

Series TH
Back or bottom-mounted. Thermal time delay switch. (15 sec. to 2 min.)

Series TDXP
Bottom or back-mounted. Explosion proof. External adjustments (1/60 sec. to 3 hrs.)

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NOR-Element Timing Circuit

Provides any of the basic timing functions

HELMUT SCHWAB
Consolidated Electrodynamics Corp.

Logical design theory has established five basic logic functions: AND, OR, NOT, memory, and time. It has already been demonstrated that each of these, with the exception of time, can be replaced by the NOR-function, and that all logic circuits except time may be synthesized with NOR-elements alone. A NOR-element consists of a resistor OR-gate with a one-transistor inverter-amplifier. The following shows how time functions too can be furnished by standard NOR-elements.

The problem

Timing problems in automatic control and data processing involve one or more of the following functions: uncontrolled time, controlled time, uncontrolled delay, and controlled delay. Each of these will be discussed separately.

Assume first that any timing circuit is triggered by an input signal, starting at time t_{01} and having a duration S as in Figure 1. This figure also shows the start time of the output signal (t_{11}), the stop time of the input signal (t_{02}), and the stop time of the output signal (t_{12}). This establishes the following:

Input signal duration $= S = t_{02} - t_{01}$
Output signal delay $= D = t_{11} - t_{01}$
Output signal duration $= T = t_{12} - t_{11}$

In addition, each timing circuit has a built-in timing period, P.

Figure 2 illustrates the four basic timing functions in terms of these intervals. It shows that, for the *uncontrolled time* function, the output interval T is independent of S, whereas for the *controlled time* function it can never exceed S, i.e., the input controls the output. In the *uncontrolled delay* function (Figure 2D) both output and delay are independent of S, and the output can only be terminated by a reset signal. For a controlled delay function, the output is again controlled by the input, and in this case if the delay D exceeds the input, there can be no output at all (Figure 2E).

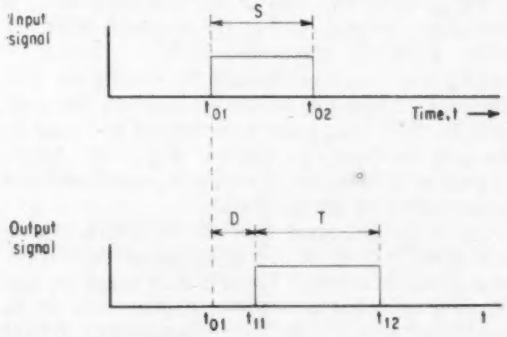

FIG. 1. Timing cycle parameters.

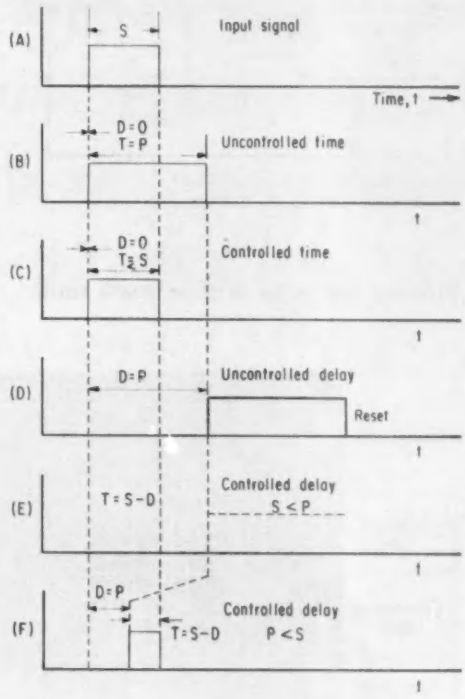

FIG. 2. Basic timing functions.

All timing devices have a certain reset time which begins at the end of the timing period. If a new triggering input signal starts during the reset time, the timing period will show an error. This error normally decreases towards the end of the reset period. The ratio of full scale timing period to reset period ranges from 1 to 100. Electrical timing devices often have a certain range within which the timing period can be varied. The ratio between the upper and lower limits of this range is called the

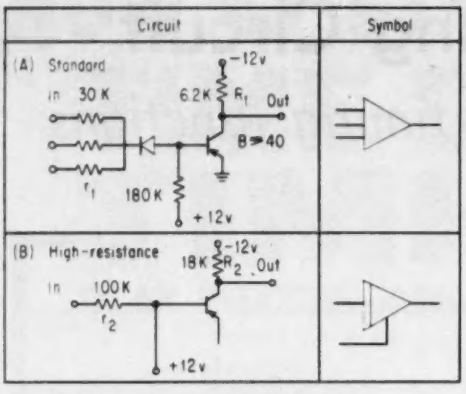

FIG. 3. Standard and high resistance NOR-element circuits and symbols.

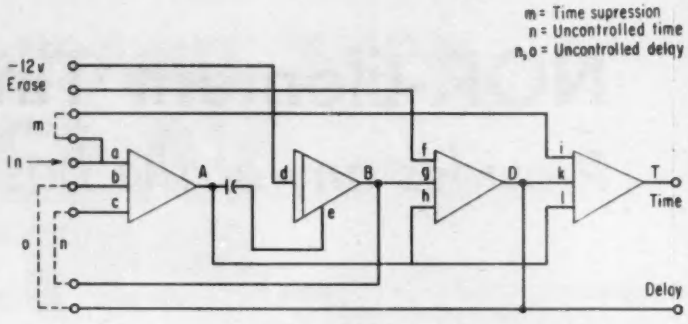

FIG. 4. Timing circuit with four NOR-elements.

Proving the logic with a truth table . . .

TABLE I

	In	a	b	c	A	e	B	f	g	h	D	i	k	l	T	Validity	Period
Uncontrolled time	X	X		X		X		X						X			t_{01}
			X			X		X						X			t_{02}
					X	X			X				X				t_{12}
Controlled time	X	X				X		X						X			t_{01}
				X	X				X				X				t_{02}
					X	X			X				X				t_{12}
Uncontrolled delay	X	X		X			X		X					X			t_{01}
			X				X		X					X			t_{02}
		X			X					X		X					t_{12}
Controlled delay S < P	X	X				X		X						X			t_{01}
					X	X			X				X				t_{02}
					X	X			X				X				t_{12}
Controlled delay S > P	X	X					X		X					X			t_{01}
	X	X				X					X		X				t_{12}
					X	X				X				X			t_{02}

. . . or by Boolean Algebra

TABLE II

$T = \overline{(i + k + l)}$, m connected

$k = D = \overline{(f + g + h)}$, $h = A$

$g = B = \bar{e}^*$

$e = A = \overline{(a + c)}$, o not connected

$c = B = \bar{e}^* = \bar{A}^* = \overline{(a + c)}^* = a^*$

In absence of an erase signal:

$D = \overline{(a^* + \overline{(a + a^*)})} = a^* \cdot a$ delay

$T = \overline{(a + \overline{(a^* \cdot a)} + \overline{(a + a^*)})}$

$= \bar{a} \cdot (a^* + \bar{a}) \cdot (a + a^*)$

$= \bar{a} \cdot a^* \cdot a^* + \bar{a} \cdot \bar{a} \cdot a^*$

$= a \cdot a^*$

range ratio, and is usually on the order of 10 or 100.

The timing circuit

Figure 3 shows two NOR-element circuits and their symbols: circuit A represents the standard NOR-element, and circuit B, a high resistance element. The complete timing circuit, shown in Figure 4, consists of three standard NOR-elements and one high resistance element. Its timing function is determined by the coupling capacitor and the 100-K input resistor of the high resistance NOR-element.

Table I is the truth table for the internal logic of the circuit. Columns *D* and *T* indicate the Delay and Time output signals corresponding to those shown in Figure 2. Each operating mode has four lines in the truth table. These correspond to the time: 1) before beginning of the input signal, 2) during the input signal, 3) during the timing period after the end of the input signal, and 4) after the end of the timing period. These times are indicated by the last column.

Boolean equations provide another way of describing the timing circuit logic. To illustrate this, Table II lists those equations peculiar to the *uncontrolled time* operation. Since it is difficult to present timing functions with Boolean algebra, asterisks have been used to indicate signals which continue to exist for a certain time after being triggered. Both tables shown prove that the behavior of the timing circuit corresponds to the function diagrams in Figure 2.

The ratio of full scale timing period to reset period is given by the ratio of the load resistor, r_2, to the unload resistor, R_1. For the proposed NOR-elements (Figure 3), this would result in a ratio of 15. Timing period can be changed by varying the load resistor, r_2. Range ratios from 10 to 25 are easily obtainable. The timing period *range* can be varied by changing the coupling capacitor (Figure 4). Limits for such a variation are given by the speed and beta characteristics of the transistors.

Currently, this same basic circuit serves to generate time functions in several numerical control systems for machine tools. Because of its simplicity and the standardization possibilities it offers, the circuit should find wide acceptance in the very near future.

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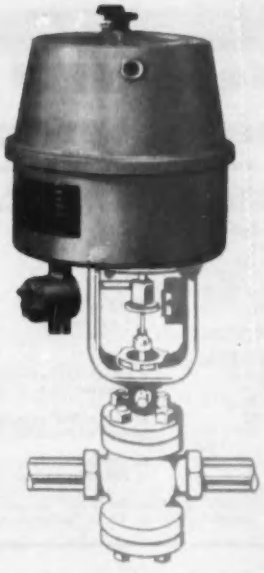
by **GPE Controls** offer the simplest, most compact, lowest-cost way to operate control valves from an electric signal. Model 698 shown positions 1¼" double-seated valve at 1000 p.s.i. pressure drop, with input signal ranges of 1-5, 4-20, or 10-50 ma. Completely self-contained. Easy, low-cost installation. Position repeatability within .002". Automatic locking with power failure simplifies start-up of process. Division I construction for hazardous service is standard. Other models available for heavier duty.



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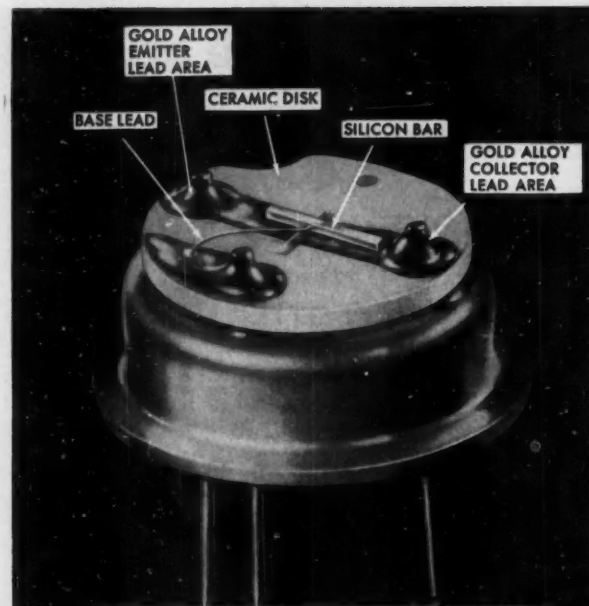
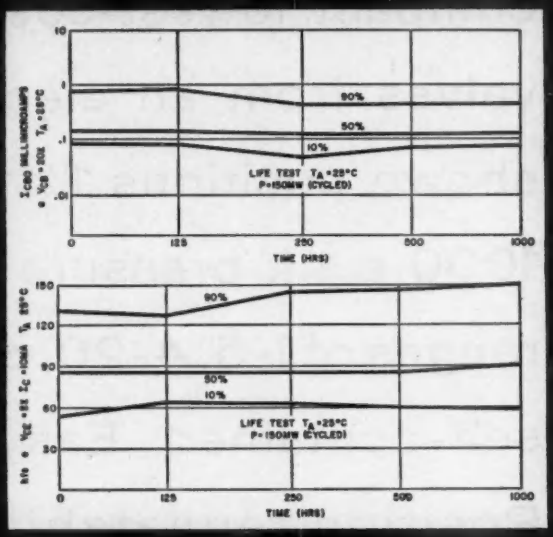


Magnified photo of silicon transistor showing Fixed Bed Construction. All parts are firmly fastened, with no suspended parts except wire lead. Transistor reacts as a solid block in resisting shock and vibration.



Charts show extreme stability of performance throughout 1000 hours of life for beta and I_{CBO}. Test conditions were 150 mw at 25°C, 200°C storage and 25 mw at 125°C. Drift rates were substantially the same under all conditions.

New NPN Tetrodes: Higher gain at high temperature and low current

LARGE QUANTITIES OF TYPES 2N36 AND 2N37 TESTED AND PROVED, HIGH RELIABILITY THE RESULT OF TWO YEARS OF MANUFACTURING EXPERIENCE*

Mechanical Reliability Test	Results	% Survival
3-ft drop-shock (2500 G's. Mil Std calls for 500G's)	2 out of 595 did not survive	99.66
Temperature cycling (−55°C to 100°C)	1 out of 375 did not survive	99.78
Life Test Reliability		
Cycled power @ 50 mw (device rated at 30 mw)	6 out of 500 exceeded parameter limits at 1000 hours	98.8
Oven @ 85°C	17 out of 500 exceeded parameter limits at 1000 hours	96.8
Shelf	No parameter failures of 500 units at 1000 hours	100.0

*General Electric's rigid standards call for only a slight shift in parameters to be a "failure." Many of these "failures" are still within EIA limits.

Here are two new germanium transistors that operate on lower voltages, require less current and are more rugged (see box below) than any other transistors that perform a like function. Furthermore, they deliver a high and constant gain at various voltages and at low power dissipation levels. Therefore, they are not only useful at high temperatures, but they also simplify circuit design and eliminate the need for close voltage regulation.

Features: Maximum gain at 1 ma, 5 volts or 5 mw. Flat gain noise factor from 1 ma to 5 ma. *Where to use them:* Mobile communications (made possible the first transistorized portable receiver). Wide band amplifier, oscillator and switching applications for radar and video at frequencies to 200 mc. *Availability:* Now . . . from your General Electric Semiconductor Sales Representative and in stock at your G-E Semiconductor Distributor's.

Absolute Maximum Ratings (25°C)	2N36	2N37	
Collector voltage to base 1 or base 2 (V_{CB})	+7	+7	V
Emitter to base 1 or base 2 (V_{EB})	+2	+2	V
Collector current (I_C)	+20	+20	ma
Emitter current (I_E)	−20	−20	ma
Base 2 current (I_{B2})	2	2	ma
Total Power dissipation	30	30	mw

Electrical Characteristics (25°C)			
Output capacity (C_{ob})	2	1.5	μμf
Noise figure (NF)	11	11	db
Input impedance (h_{ie})	100-j27	80-j10	ohms
Current transfer ratio (h_{fe})	$2.2\angle -81°$	$1.1\angle -100°$	
Common base cutoff frequency (f_{ab})	50 MIN.	90 MIN.	mc
Common Emitter power gain (G_e)	11.5	9	db
Measurement frequency	60	150	mc

stability of G-E silicon transistors

Uniform characteristics out to 1000 hours exhibited by silicon transistors featuring Fixed Bed Construction

Comprehensive tests performed on General Electric silicon transistors show remarkably stable performance throughout 1000 hours of operation at high temperatures. Each test was run on seven lots of fifty Type 2N337 or 2N338 transistors (part of the series 2N332 through 339). These are the results:

350 units were given a 150 mw operating test at 25°C.

Only two units exceeded parameter limits, a successful performance rate of 99.4 percent.

350 units were given a 200°C storage test.

Only three units exceeded parameter limits, a successful performance rate of 99.1 percent.

Fixed Bed Construction, plus stabilized processing makes these results possible. No fluxes, resins or solders are used — only a gold alloy which forms an integral bond between all parts.

Besides the demonstrated electrical characteristics, General Electric's silicon transistors can absorb physical punishment far beyond normal specifications. All parts are solidly fixed together and react as a solid block in resisting shock and vibration. Test units have been fired from a shotgun, struck with a golf club and rattled freely in an auto hubcap for 700 miles—and worked afterward.

Electrically and mechanically, this series of transistors is the most thoroughly tested and proved today—your assurance of high stability and reliability. Call your General Electric Semiconductor Representative for further details.

ABSOLUTE MAXIMUM RATINGS AT 25°C

	2N332-6	2N337-8	
Collector to base voltage	45	45	volts
Emitter to base voltage	1	1	volt
Collector current	25	20	ma
Collector power dissipation	150	125	mw
Operating temperature	−65°C to 175°C	−65° to 150°C	

Now available—4 new NPN alloy transistors

Absolute Maximum Ratings at 25°C	
Collector to base voltage	20 volts
Emitter to base voltage	15 volts
Collector to emitter voltage	20 volts
Collector current	300 ma
Base current	50 ma
Emitter current	300 ma
Storage temperature	85°C to −65°C
Operating junction temperature	85°C
Power dissipation	150 mw

Four new germanium switching transistors, made by the highly controllable NPN alloying process, are now being warehoused by General Electric and its distributors. The four transistors, Types 2N634, -5, -6 and 2N388, feature extremely consistent parameters. I_{CO} for instance, multiplies up in a normal fashion, so that higher temperature I_{CO} may be predicted from low temperature readings.

The transistors provide 150 mw power dissipation. They are useful in emitter-follower applications in computers, high current flip-flops, and are ideal as complementary devices to PNP computer transistors, such as the 2N396.

For complete information call your General Electric Semiconductor Sales Representative, your G-E Semiconductor Distributor, or write Section S16119, Semiconductor Products Dept., General Electric Company, Electronics Park, Syracuse, New York.

GENERAL ELECTRIC

Semiconductor Products Dept., Syracuse, New York

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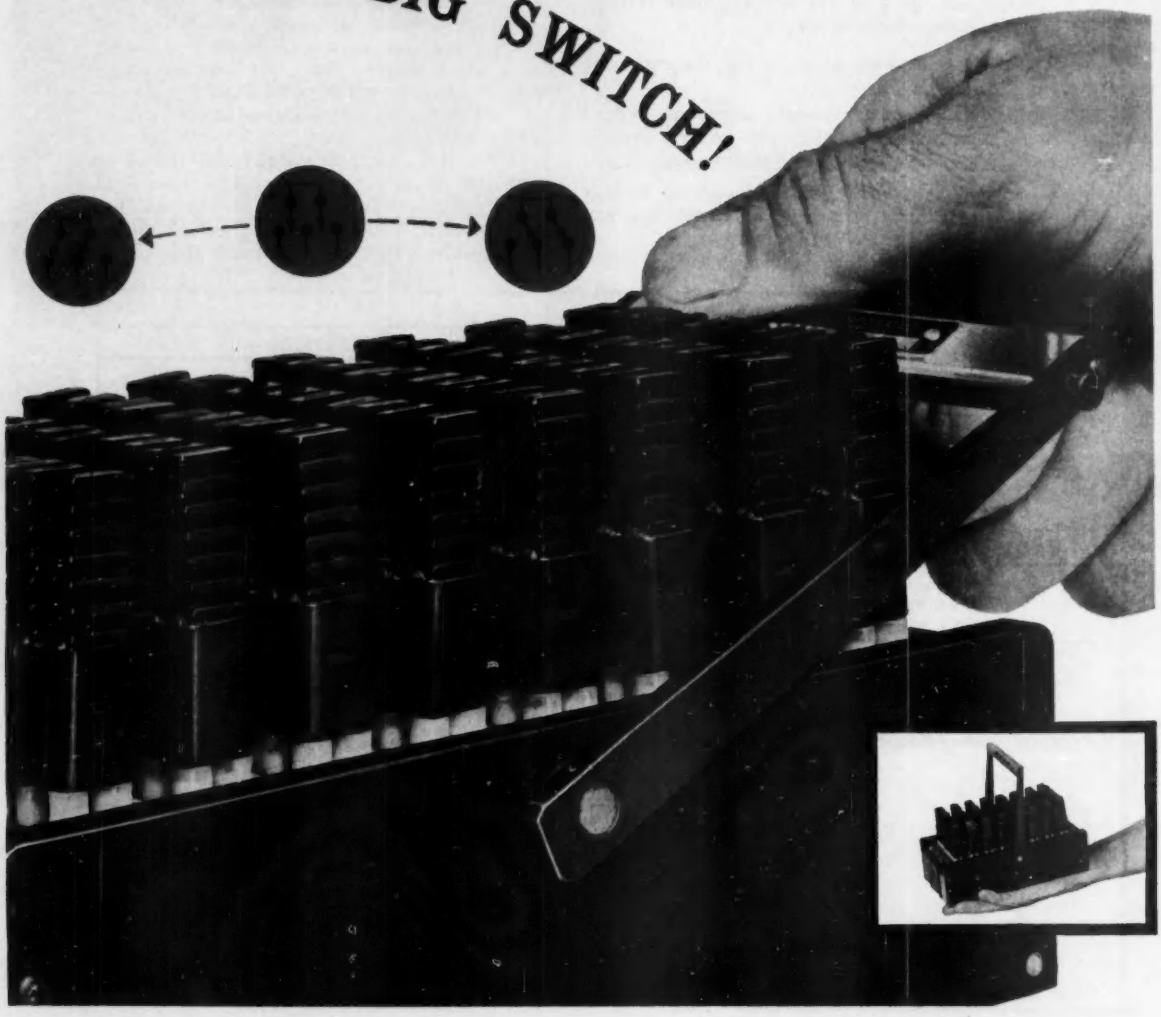

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Simple Circuit Controls Spacing on Conveyor Lines

R. L. DeLOACHE
Cleveland Electric Co.

The two-belt conveyor setup shown in Figure 1 will uniformly space objects of any length on belt 2 when combined with the circuitry in Figure 2. The circuit is simple, reliable, and universal in application. It is believed an improvement over similar circuits formerly used. Objects to be spaced need not be of uniform size or shape. The speed of operation is limited only by the mechanical limitations of the conveyor system. Objects could range from laundry bundles to steel ingots.

This circuit has been in successful use for more than a year at Southern Spring Bed Co., Atlanta, Georgia, in connection with a machine especially designed to automatically spray seating cushions. Down time for maintenance has been at a minimum.

The elementary diagram in Figure 2 has been simplified to show only the circuitry controlling the actual spacing operation. All extraneous components such as motors, clutches, and starters have been omitted. The two photoelectric cells are not shown but only the relays *A* and *B* which are actuated by these cells. The relays that control spray nozzles are not shown.

In Figure 1, belt 2 moves continuously at a constant rate in the direction of the arrow. Belt 1 moves in the same direction, but its movement is controlled by eyes *A* and *B*. This belt is driven through a magnetic clutch permitting fast starts and stops. Eye *A* stops the belt; eye *B* starts it moving.

The spacing of eyes *A* and *B* is adjustable, and their center-to-center distance determines the spacing of the cushions on belt 2. These eyes control the magnetic clutch driving belt 1, starting and stopping the movement of this belt at the right instant to uniformly space the cushions on belt 2. Belt 1 moves slightly faster than belt 2.

In Figure 2, relay contact *A* closes whenever beam A is interrupted. Likewise, relay contacts B_1 and B_2 operate whenever beam *B* is interrupted. Relay *R* is a two-pole relay with normally-open contacts and has a resistor in series with its operating coil *R*.

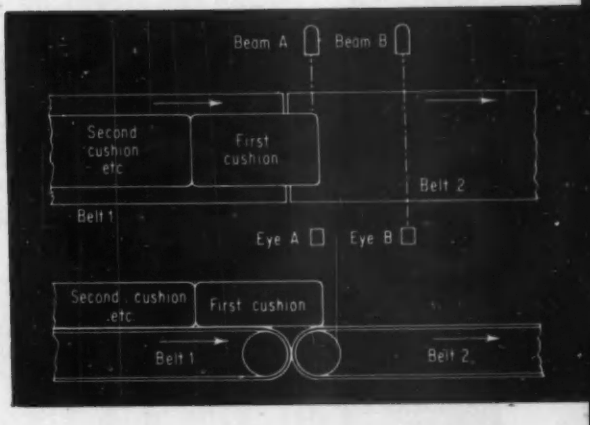
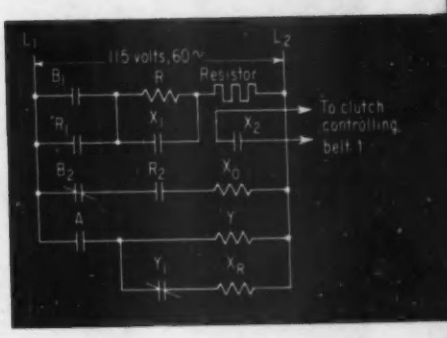


FIG. 1. Two-belt conveyor system used with automatic spacing system. Belt 2 moves continually. Belt 1 is controlled by objects interrupting photocell circuits.

FIG. 2. Relay circuitry used with system in Figure 1. Relay X is mechanically latching, closed by X_0 released by X_R.



Relay Y has a single normally-closed contact Y_1. Relay X is of the mechanically latched type and has two normally-open contacts X_1 and X_2. When X_0 is energized it closes contacts X_1 and X_2. These contacts are held closed by the latch after X_0 is de-energized. Momentarily energizing X_R releases the latch allowing the contacts to open if X_0 is not energized.

The operating sequence is as follows: Assuming no cushions on either belt, power is turned on and belt 2 begins to move. Belt 1 may or may not move depending upon whether relay X is latched "in" or not. If belt 1 does not move it can be set in motion by momentarily interrupting beam *B* with the hand. Photoelectric relay contacts B_1 will close and B_2 will open. A circuit will be established from L_1 through coil *R* and through the resistor to L_2. R_1 will close and seal-in around B_1. Also, R_2 will close. This sets up the circuit to X_0, but the circuit will not be completed until the operator removes his hand from eye *B*. Then B_2 will reclose, energizing X_0 from L_1 through B_2 to R_2 through X_0 to L_2. X_2 will close to energize the clutch circuit. Simultaneously X_1 closes, short circuiting coil *R*, dropping out contacts R_1 and R_2. The resistor limits the short circuit current through X_1 to a low value. Contacts X_1 and X_2 are mechanically held closed. And belt 1 will continue to run.

Cushions may be of various lengths, intermixed. They are placed lengthwise on belt 1 as shown in Figure 1. The first cushion will be propelled to eye *A* where it will stop belt 1 by blacking out this eye and closing contact *A*. A circuit is completed from L_1 through *A* through Y_1 to coil X_R to L_2. This will trip the latch on X, opening X_2 and de-energizing the clutch.

At this point it will be noted that Y_1 will open and will remain open so long as *A* is closed, and it might be thought that Y_1 will open before the latch can be tripped, but in actual practice such is not the case. (Relay X closes faster than relay Y).

It is now necessary for the operator to momentarily interrupt beam *B* with the hand once again. The machine is now in automatic operation and the cycle will be repeated over and over with no further attention by the operator except to see that belt 1 is loaded.

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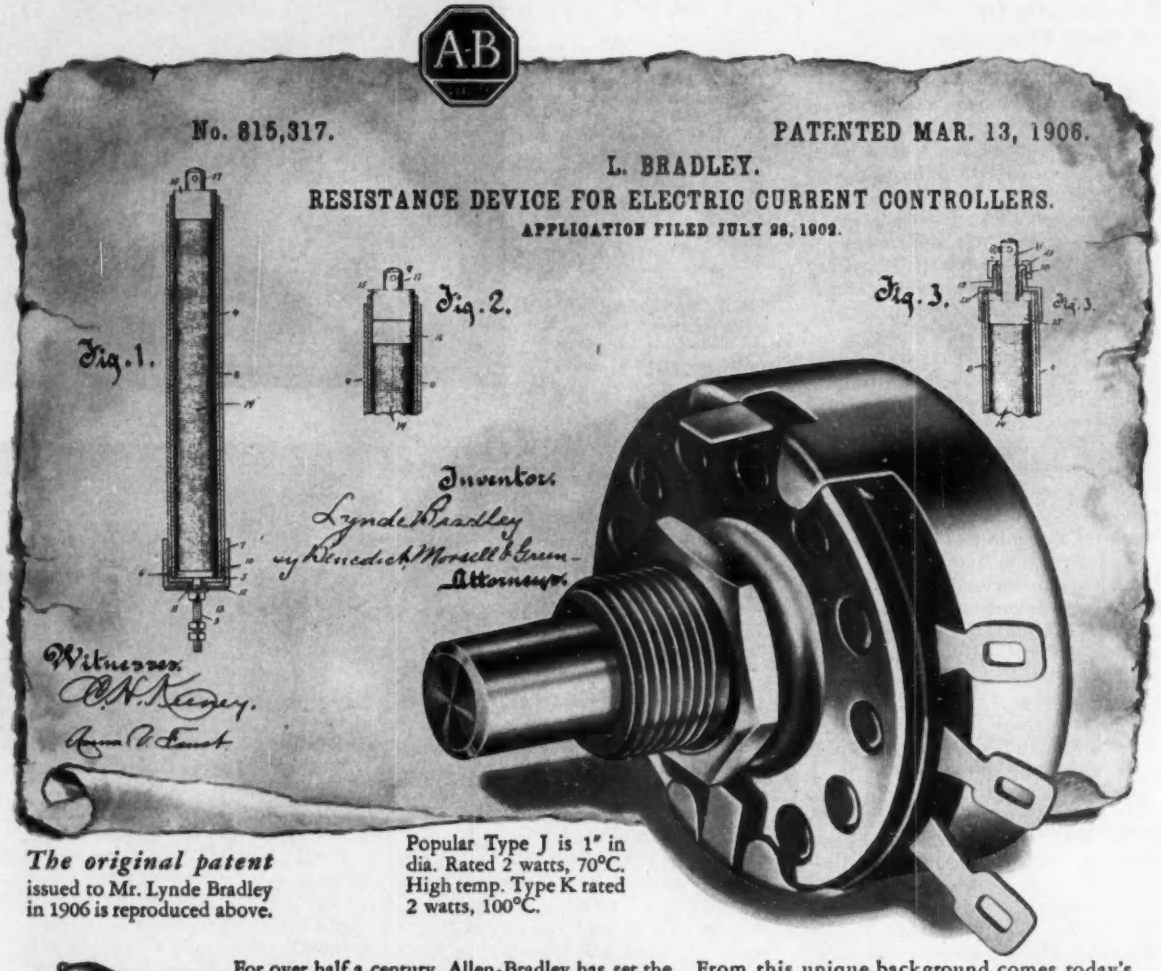

The original patent issued to Mr. Lynde Bradley in 1906 is reproduced above.

Popular Type J is 1" in dia. Rated 2 watts, 70°C. High temp. Type K rated 2 watts, 100°C.

Tiny Type G, ½" dia. Rated ½ watt, 70°C. Type L, ½ watt, 100°C.

New Type R adjustable fixed resistor rated ¼ watt at 70°C ambient.

For over half a century, Allen-Bradley has set the pace in the development of quality variable resistors—and continues to do so today! With the original patent, illustrated above, Allen-Bradley introduced a new concept in the field of variable resistors. And in the early days of radio, Allen-Bradley variable resistors were so universally accepted for their smooth control that famous "Bradleystats" were a byword of the wireless era.

From this unique background comes today's famous A-B family of variable resistors, all of which feature the solid, hot molded resistance element—an *exclusive* A-B design that has proven unequaled for reliability and long life. It is because of this superlative performance that Allen-Bradley variable resistors enjoy the enviable reputation of being "required" in so many critical military and industrial applications.

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ALLEN-BRADLEY
Quality Electronic Components

Circulating Water Temperature Control

To get close control of inlet temperature for a special circulating-water heat exchanger, this system had to control the outlet temperature of a "process" consisting mainly of 16 ft of 12-in. pipe just ahead of the exchanger.

D. W. RICHMOND
Monsanto Chemical Co.

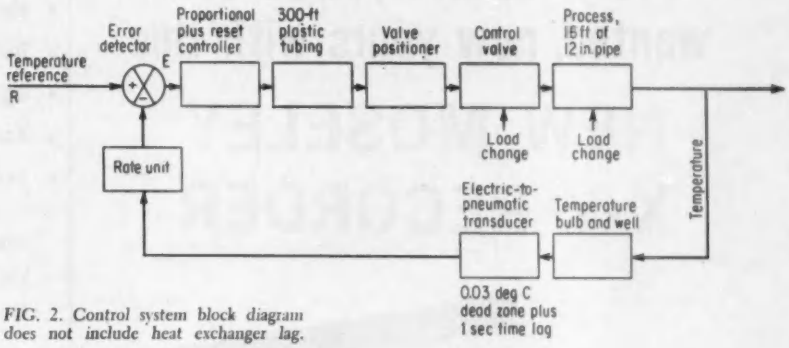

FIG. 2. Control system block diagram does not include heat exchanger lag.

Optimum operation of a special purpose heat exchanger depends on close control of inlet circulating water temperature. A recently installed temperature control system limits overshoot on startup to 0.2 deg C and thereafter holds temperature within plus or minus 0.05 deg C even under continual load changes. Such close control is vitally necessary in the chemical process using this heat exchanger. The control system has therefore been a determining factor in the success of the complete setup.

Figure 1 is a layout of the major equipment. A 2,000-gpm pump circulates water through the heat exchanger via 16 ft of 12-in. external piping. When heat must be added to the heat exchanger, steam passes through control valve V_2 into two direct-contact mixing-type steam water-heaters. The heaters are located 10 ft and 14 ft from the suction side of the pump—far enough away to avoid cavitation. Water valve V_1 is closed during the heating cycle. When cooling of the heat exchanger is required, fresh water is admitted to the suction side of the pump through V_1, steam valve V_2 is shut off. Excess water and condensate overflow through a vented surge chamber to the sewer.

The temperature of the circulating water on the discharge side of the pump is sensed by a nickel wire resistance temperature detector, sealed in a thin stainless steel well designed for high speed measurement. This detector is located 2 ft from the pump outlet. A temperature controller positions automatic steam valve V_2 in compliance with signals from the primary temperature element during the heating cycle only. The temperature of the water entering the heat exchanger is recorded on an electronic 12-in. circular chart two-pen recorder with a range of 20 deg C. The temperature measurement is converted to a pneumatic signal by an electric-to-pneumatic transducer inside the recorder and then passed to a stack-type pneumatic controller in which the rate response is ahead of the proportional-plus-reset controller. The pneumatic signal from the controller travels 300 ft through ¼-in. OD plastic tubing to the valve positioner on the diaphragm motor valve V_2. V_2 is a 1½-in. normally-closed double-seated valve with equal-percentage flow characteristics and has Teflon packing to keep stem friction low.

Note in Figure 1 that the heat exchanger with its time lag is not included in the temperature control circuit. Actually, the "process" consists of a 16-ft section of 12-in. pipe, the two steam water-heaters, and the centrifugal pump, which also serves as a good mixer. The control block diagram of the process, including the controller, is shown in Figure 2.

The transportation lag between the heaters and the temperature bulb is only 0.37 sec. Since the time constant of the temperature well is guaranteed by its manufacturer to be only less than 2 sec. this is a case where instrument lags are many times greater than the process time constant.

The proportional band of the controller is set at 30 percent and reset action is adjusted to 1 min per repeat. The rate action (ahead of the error detector) is set at 2 min. The optimum value of 6 to 7 min cannot be used because of "noise" caused by a 0.03 deg dead zone in the electric-to-pneumatic transducer.

There are two load changes acting upon the system: 1) the rate of heat input to the heat exchanger and 2) changes in steam supply pressure, which is 80 psig plus or minus 5 psi. Fortunately the load changes are relatively slow compared to the total lag in the temperature control loop, which explains the good performance of the control system in this process.

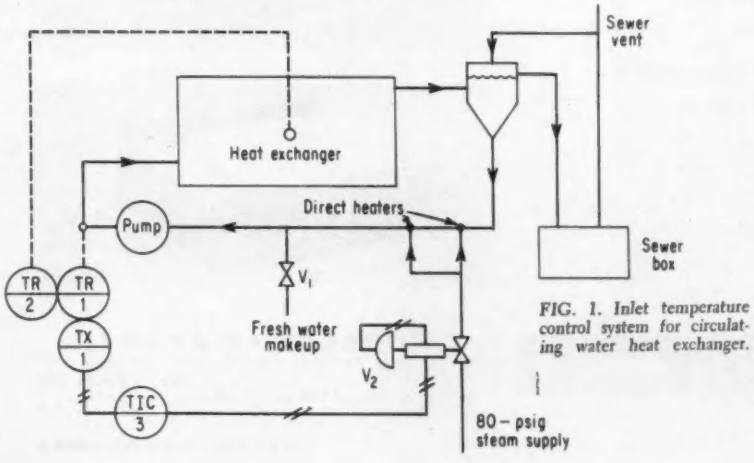

FIG. 1. Inlet temperature control system for circulating water heat exchanger.

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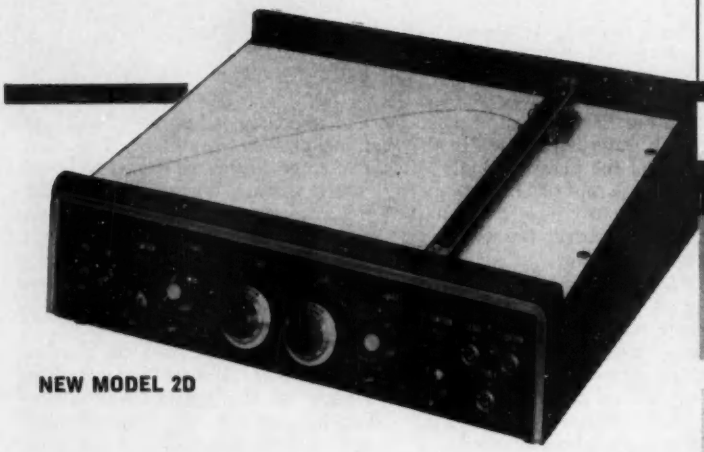

NEW MODEL 2D

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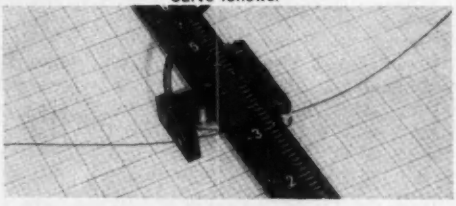
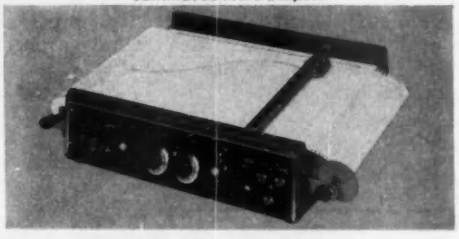
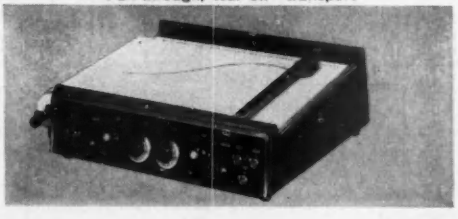
Curve follower



Continuous roll transport



"Pull-through, tear off" transport



Model 2D is a significantly advanced X-Y Recorder offering virtually every useful Recorder capability, plus a new control panel arrangement insuring maximum operating convenience. Brief specifications are: Input range 7.5 mv to 150 v on X-axis; 5 mv to 100 v on Y-axis. X-axis time base, 5 steps, 7.5 to 750 secs. Input resistance 200,000 ohms/v, accuracy and resolution ± .2%, zero offset, pen speed 20 in/sec each axis, vacuum paper hold-down.

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5631

Inertial Techniques Improve Rate-of-Climb Indicators

High accuracy rate-of-climb indication for high performance aircraft posed several difficult problems. Inertial sensing techniques and a cadmium sulfide photocell helped solve them.

BIRCH FORD,
Summers Gyroscope Co.

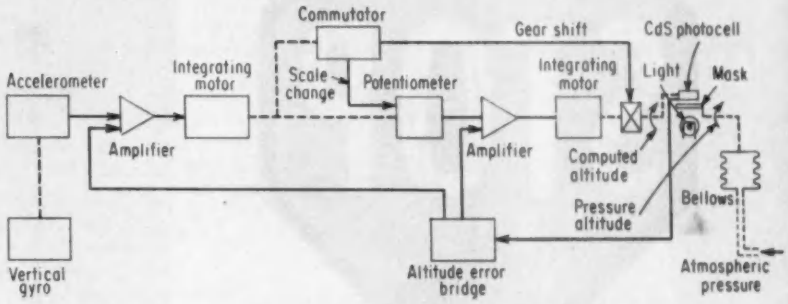

FIG. 1. Instantaneous vertical velocity indicator (IVVI system) for altitude rate-of-climb indication in high performance aircraft.

Standard aircraft rate-of-climb instruments based on the "leaky bellows" principle have time responses too slow for modern military requirements—1 min at 80,000-ft altitude, for example. A new instantaneous vertical velocity indicator (IVVI) has a constant time lag of about 100 millisec that does not depend on altitude.

In the IVVI system, vertical velocity is computed by integrating the output of an accelerometer mounted on the inner gimbal of a vertical gyro. A 1-g bias cancels the nominal acceleration of gravity.

In such a system, small errors in the accelerometers, the transducer, and the integrator would accumulate to make the indicated vertical velocity grossly in error within a few minutes' time. Error accumulation is prevented in the IVVI system by integrating the computer vertical velocity for altitude, comparing this computed altitude with pressure altitude, and feeding back the altitude and error signal to both the velocity and acceleration channels. The feedback percentage is small—just enough to compensate for the maximum probable error in the computing system plus the maximum apparent variation of gravity. (The exact value of g can vary as much as 1 percent with geographical location, altitude, and flight direction.) Wide tolerances in the feedback gain make system adjustments noncritical.

The IVVI system is diagrammed in Figure 1. Proprietary gyros and miniature integrating motors of Summers Gyroscope Co. were easily adapted to this system. Major design problems:

- an ultralow-torque dc transducer with high resolution and accuracy to provide a signal representing vertical velocity without loading the first integrator. Commercial single turn potentiometers did not have enough resolution, and multiturn potentiometers required too much torque. This problem was solved by designing a special three-turn potentiometer with an operating torque of 0.05 in.-oz.
- an operating range of 10,000 to one. The integrators and other components could not maintain the required accuracy over this range so the problem was solved by literally shifting gears in the altitude computing unit. Since altitude must be computed and compared with pressure altitude for the long time corrections, the entire system must operate accurately over a range of 60,000 ft per min, although it need indicate only up to 6,000 ft per min. For instrument landings the system must be sensitive to rates as low as 6 ft per min.
- a high gain dc differential transducer for the altitude error signal. The altitude error signal was required to have a gain on the order of 10 vdc per 0.001-in. motion of the transducer. Many conventional ac inductive and capacitive type pickups were tried with

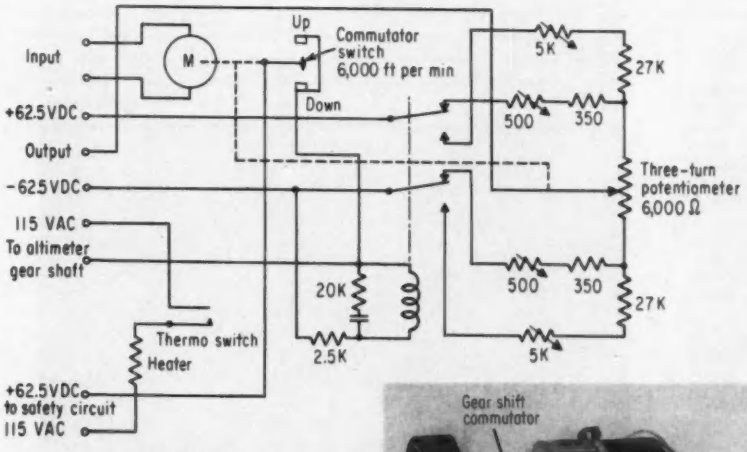

FIG. 3. Rate-of-climb indicator wiring diagram.

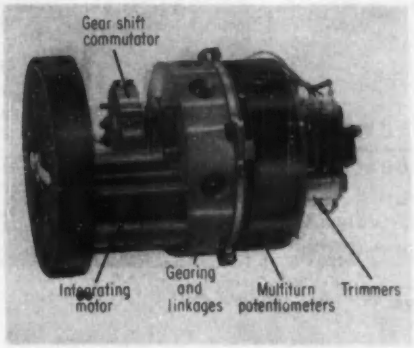

FIG. 2. Rate-of-climb indicator used in IVVI system.

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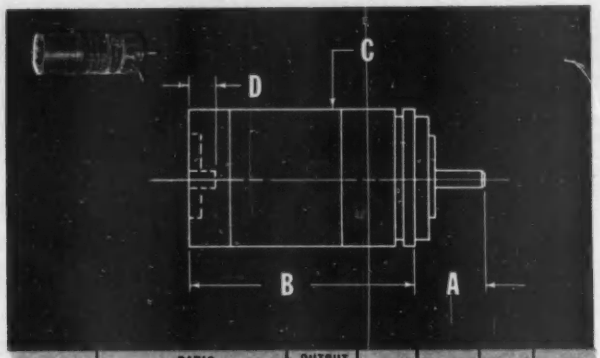
- **SPEED REDUCERS**

Bowmar single-unit 2-speed gearchangers can reduce the weight and size of any control package or system which requires or which could be improved by multi-speed operation. Such systems typically include those which may benefit from fast slewing and slow zeroing. These Bowmar gearchangers permit extremely fast system dynamic response, plus slow fine-tune modes of operation which reduce inertial hunting effects.

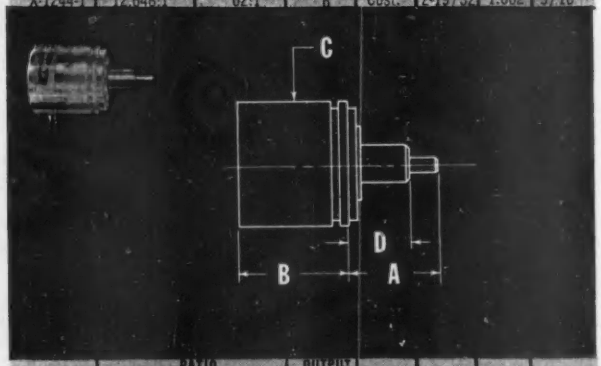
Scarcely larger than a gearhead or speed reducer alone. Bowmar's new gearchangers are electrically operated and are completely self contained. They eliminate the need for outboard mechanisms, extra mounting plates and "accident prone" shifting complexes.

Bowmar produces these precision gear changers in sizes from 11 to 23, in all ratios and ratio differentials. Units shown are representative of a few Bowmar types.

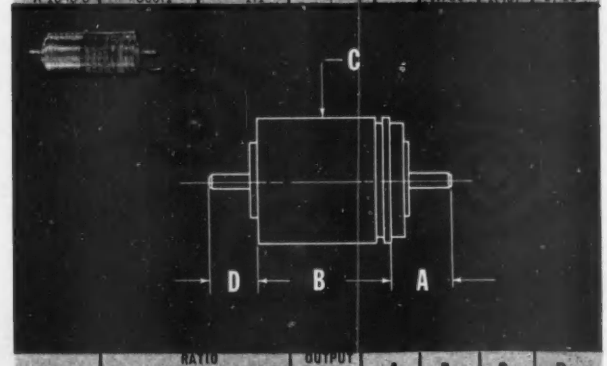
Send for Data Package 1159



PART NO.	RATIO ENERGIZED	RATIO DE-ENERGIZED	OUTPUT TORQUE (IN.-OZ.)	A	B	C	D
X- 801-1	36,600:1	20:1	6	3/8	3-11/32	1.437	9/16
X- 863-1	8:1	*1:1	3	7/16	2.000	1.062	7/16
X- 924-1	470,000:1	320:1	24	11/16	3-11/32	1.437	7/16
X- 989-3	42,978:1	26:1	5	5/8	2.450	1.062	7/16
X- 709-1	24,000:1	2,400:1	6	5/8	2.450	1.062	7/16
X- 740-1	10,000:1	100:1	6	11/16	2.376	1.437	7/16
X-1244-1	12,648:1	62:1	6	Cust.	2-19/32	1.062	9/16



PART NO.	RATIO ENERGIZED	RATIO DE-ENERGIZED	OUTPUT TORQUE (IN.-OZ.)	A	B	C	D
X- 637-1	6:1	*1:1	16	.860	1.062	1.500	.563
X- 691-3	50:1	*1:1	10	1	2.058	1.750	5/8
X- 853-1	135:1	*1:1	5	1-3/32	1.994	1.437	23/32
X- 853-2	10:1	*1:1	5	1-3/32	1.994	1.437	23/32
X-1240-1	18,500:1	50:1	4	1.132	2.750	1.437	.632
X-1240-2	5,000:1	50:1	4	1.132	2.750	1.437	.632
X-1343-3	300:1	*1:1	4	1	1.750	1.437	9/16



PART NO.	RATIO ENERGIZED	RATIO DE-ENERGIZED	OUTPUT TORQUE (IN.-OZ.)	A	B	C	D
X- 748-1	36,600:1	20:1	4	1/2	2.215	1.062	15/32
X-1008-1	36:1	*1:1	8	11/16	1-17/32	1.437	9/16
X-1008-2	1,463:1	*1:1	8	11/16	1-17/32	1.437	9/16

BOWMAR INSTRUMENT CORPORATION

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Precision Electromechanical Controls and Instrumentation, Servomechanisms
Precision Miniature Gearheads, Navigational Counters, Indicating Devices

voltage amplifiers and ac to dc conversion circuits. Such pickups directly generate only microvolts or a few millivolts per 0.001 in. of motion and all of them proved unsatisfactory because of the high gain and noise problems encountered. Summers Gyroscope Co. has been developing cadmium sulfide photocells for two or three years but had not applied them in any instrument. A cadmium sulfide photocell proved to be the solution for this transducer problem. A photocell pickup weighing about ¼ oz was mounted on a yoke driven by the second integrating motor through a high-ratio gear train so that the yoke moves linearly through approximately 83 deg of rotation for 80,000 ft of computed altitude. A light mask between the photocell and the light source is also driven through 83 deg for 80,000 ft of pressure altitude by a bellows and nonlinear linkage.

The dc output voltage of the photocell bridge is essentially proportional to the difference between computed and pressure altitudes and has an output sensitivity of about 100 millivolts per ft of error. The photocell bridge limits at approximately 400 ft error.

The rate of climb indicator is pictured in Figure 2, and its wiring diagram is shown in Figure 3. The indicator hand is driven by a pin and slot arrangement to provide a logarithmic scale calibration. The gear shift commutator and potentiometer are driven through straight gearing. When the hand reaches 6,000 ft per min indicated, the pin leaves the slot and disengages the hand. The commutator and potentiometer, however, continue to rotate up to an equivalent limit of 60,000 ft per min. The bimetal-operated heater warms the unit for low temperature operation.

At 6,000 ft per min indicated the commutator operates a relay to change potentiometer output by exactly ten to one. The commutator also operates a gear shift solenoid to reduce the gear ratio to the photocell yoke on the second integrator motor by a factor of ten to compensate for the similarly reduced voltage to the motor.

The pressure altimeter does not have to be especially good to yield average rate-of-climb accuracies far better than standard instruments.

Pulse Circuitry for a Transistorized Photocounter

WILLIAM N. SICK, JR.,
Texas Instruments, Inc.

Most of the problems normally associated with electronic photocounters have now been eliminated by the development of a transistorized counter. No vacuum tubes or phototubes or high-voltage power supplies mean less bulk and weight, more reliability.

The transistorized counter has pulse circuitry rather than linear amplifiers, thus eliminating sensitivity adjustments and making the output pulse duration independent of the duration of light beam interruption. Breaks in the beam of less than a millisecond can be counted. The maximum repetition rate is limited only by the operating time of the output relay.

The Type 800 phototransistor is a light-sensitive switch. When the bar is illuminated, the collector current increases from about 20 microamp to over 150 microamp. The phototransistor is most sensitive to light in the red end of the visible spectrum. This property makes it possible to use less than the rated voltage on the light source. Although the total light is reduced, there will be little reduction of light output in the red region. A 25 percent reduction in lamp voltage can increase lamp life to 50 times its original life expectancy. The required light from the source can be further reduced if a lens is used to focus the light on the phototransistor.

Figure 1 is a block diagram of the counter; the schematic is given in Figure 2. When the light beam that illuminates the phototransistor is broken, a saturated transistor switch is turned off. The rise and fall times of the output pulse from the switch depend on how quickly the light beam is broken. Since this rise time may be several milliseconds, the pulse is fed through a Schmitt trigger or squaring circuit, having an output rise and fall time of a few microseconds. The leading edge of this pulse triggers a one-shot multivibrator. The one-shot produces a 0.2 sec output pulse, independent of the duration of the light interruption and ensures that the output is always long enough to operate the mechanical counter.

The relay in the emitter circuit of Q_8, shown on the schematic, can be replaced by any load greater than 1 K ohm that will operate on 10 volts. If a lower impedance output is desired, another transistor can be added. Slight modifications of the output stage make a wide variety of applications possible.

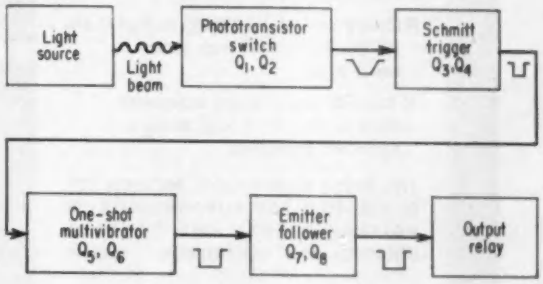
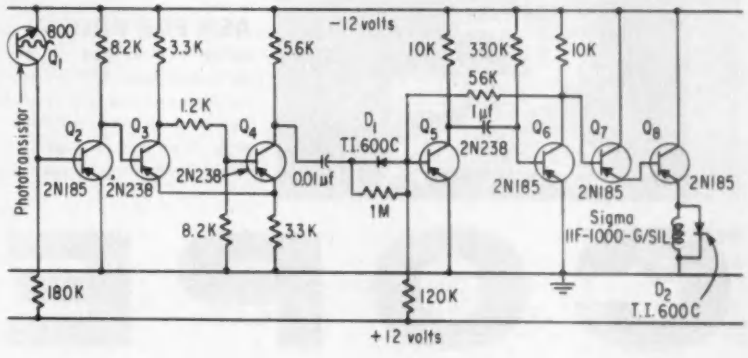


FIG. 1. Photocounter block diagram.

FIG. 2. Complete circuit for stable transistorized photocounter.



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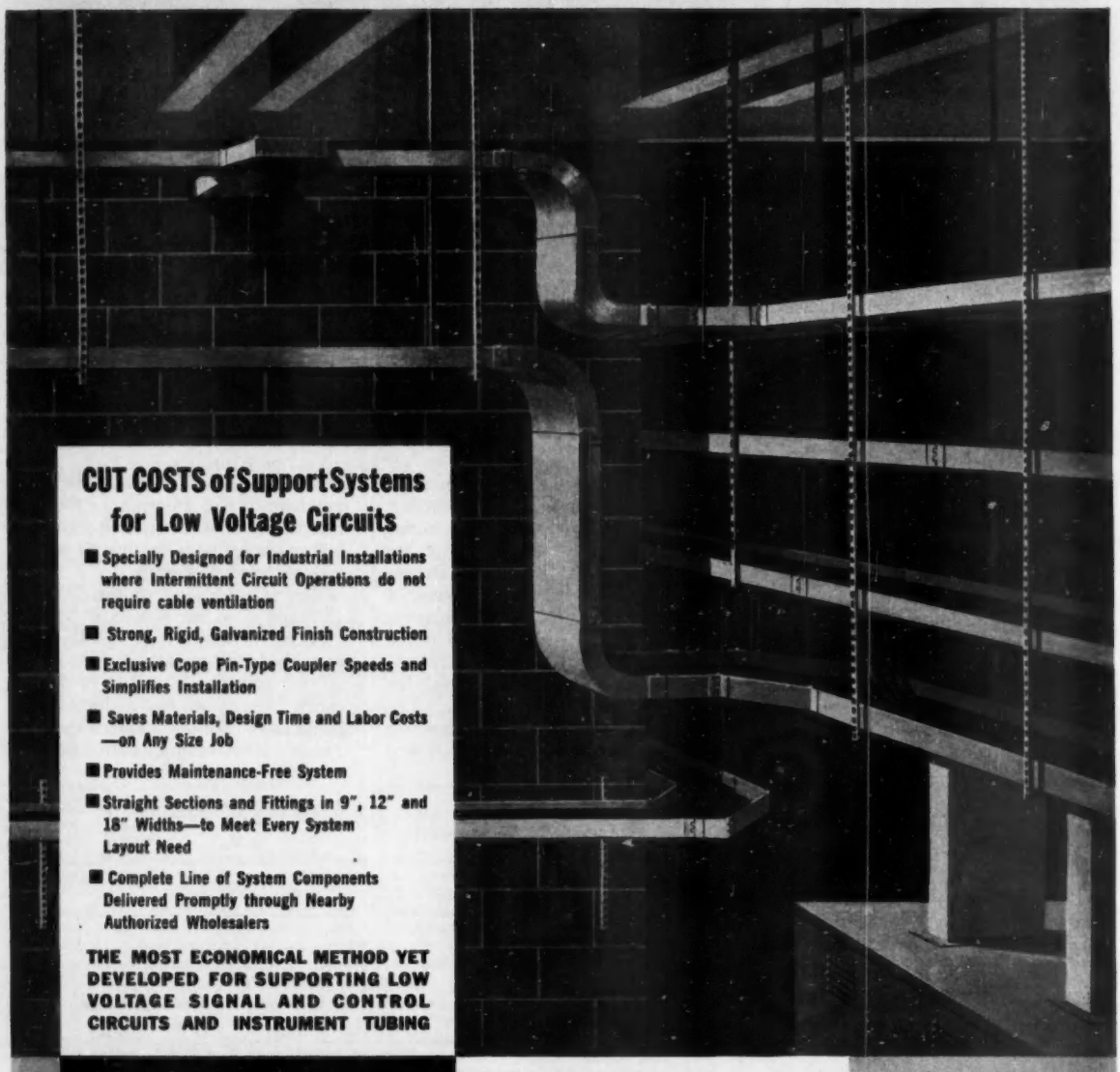

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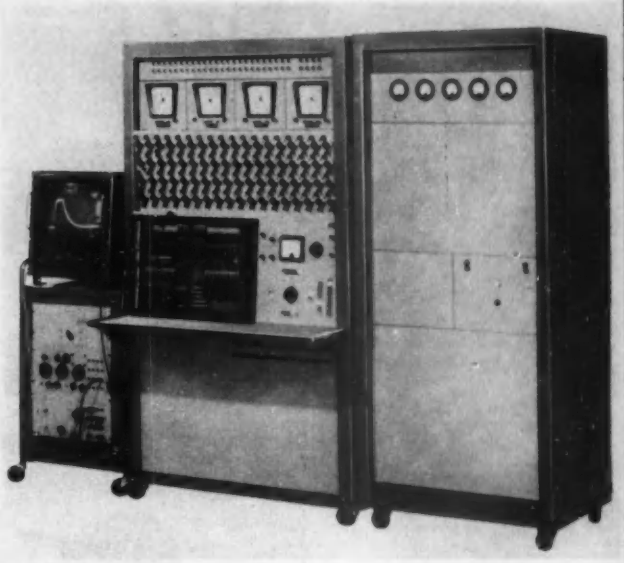

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SMALLEST RECORDER takes 2,000 g's

Shown in the hands of 5-yr old Lee Engdahl, this miniature airborne tape recorder weighs only 10½ oz, occupies 14 cu in., and can withstand over 2,000 g's shock. In missile and satellite applications, it will record from 1 to 16 channels of input data on a continuous tape and play it back to ground support receivers. Power consumption is a low 1½ watts.

The previous "world's smallest" tape recorder, made by the same company, weighed more than twice as much as this model. An interesting commercial application, cited by company engineers, is in oil well drilling where the entire recorder can be placed inside a 3-in. pipe.

Available accessories include: transistor timing oscillators, Zener diodes, bias supplies, bias oscillators, dc amplifiers, battery packs, and various types of containers.—Leach Corp., Los Angeles, Calif.

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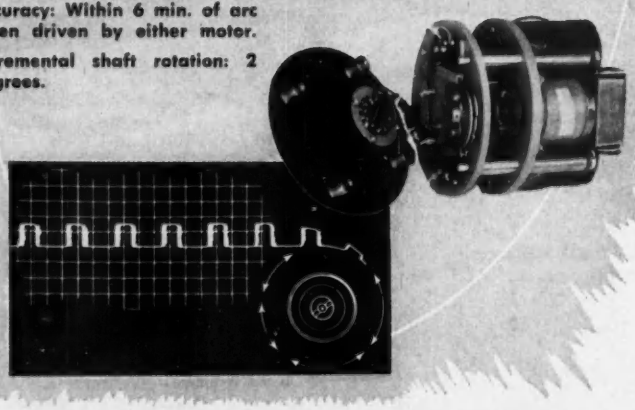

This is one of the many applications for the Stepper Motor — a device for translating electrical pulses into accurate, bi-directional, incremental shaft displacements.

The Synchro Positioner uses two Stepping Motors, an Autosyn differential, and a built-in pulse generator. One motor positions the Autosyn Shaft in coarse increments in either direction, while the other motor, using a different gear ratio, positions the same shaft in vernier increments in either direction. As the reset command signal is of steady-state type, the built-in pulse generator permits use of the driving motors for the reset function.

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Subsidiary of California Eastern Aviation, Inc.
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COMPACT TAPE RECORDER

The PS-214 recorder/reproducer is a 100-lb, 14-channel magnetic tape instrument designed to provide laboratory precision in a portable cabinet. Completely transistorized it features modular construction and printed circuit boards to permit the interchange of up to 14 direct or FM channels. Its magazine loading feature is designed for rapid replacement of tape or substitution of a continuous loop magazine. Applications include high frequency recording, low frequency data handling, investigation of transient phenomena, and quasi-static measurement. A variety of data can be recorded concurrently with a common time base.—Precision Instrument Co., San Carlos, Calif.

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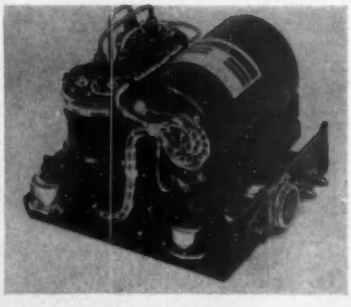

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351 AC MULTI-CURRENT MONITOR	333 LINE SERVICE MONITOR
352 LINE FREQUENCY MONITOR	(a single-package combination of 352, 353, and 354)

Only the "recti/riter" systems, recorders and matching accessories, offer these wide ranges for recording electrical parameters:

10 millivolts to 1000 volts . . .
500 microamperes to 1000 amperes . . .
Monitor standard frequencies—40, 60, 400 cps.

FULL SCALE RANGES—Accessory scales give quantities per division equal to decimal multiples or sub-multiples of 1, 2, and 5 in keeping with standard 50-division chart of recorders.

ACCURACY—Combined recorder-accessory response departs from true value at any point not more than 2 per cent of the full scale value.

POWER REQUIREMENTS—No auxiliary power required for transducer accessories . . . a 45-volt battery or optional AC supply is used with the DC Amplifier.

SIZE—Aluminum cases 2½" H., 7½" W., 10" D. (Monitors may be mounted inside as integral part of recorders.) Mountings are available for relay racks, flush mounting, portable, or desk use.

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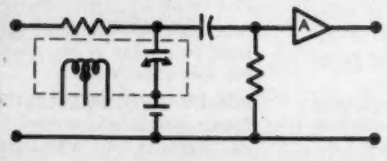

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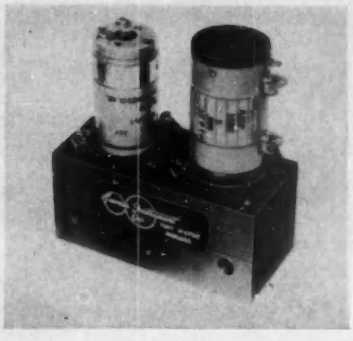
one temperature probe, and a single servo computer. According to the manufacturer, its simple electromechanical computer combines all the advantages of an all-mechanical instrument with the accuracy and reliability of a more complex multiple-servo device.–G. M. Giannini & Co., Inc., Pasadena, Calif.

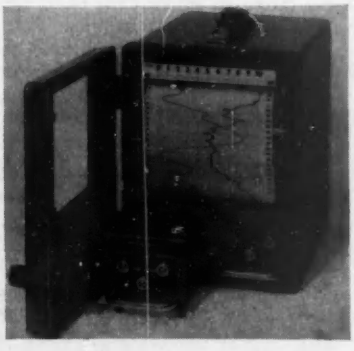
Circle No. 283 on reply card



SERVO PACKAGE

This miniature servo package pictured above provides the linkage between an analog and digital computer in a new conversion system. It consists of two gear clusters with a ratio of approximately 40:1 between the size 8 servomotor and a 1-k pot. An internal slip clutch, set at from 10 to 15 oz-in., protects the pot stops. Complete package measures 2⅜ in. long by 1½ in. wide.–Bowmar Instrument Corp., Fort Wayne, Ind.

Circle No. 284 on reply card



TWO-CHANNEL RECORDER

Shown is the panel mount version of the new Varian G-22 potentiometer recorder, a compact 2-channel instrument in which both pens traverse the full width of a 5-in. strip chart. Avail-

LIMIT SWITCHES WITH 1½" OUNCES SENSITIVITY... IMMUNE TO VIBRATION

National Acme Super-Sensitive Limit Switches provide the highest possible degree of control reliability. Extremely compact, they are sensitive to forces as low as 1½" ounces*, and yet have machine tool ruggedness to withstand vibration. Reliable, accurate service is assured throughout millions of contacts.

For extreme operating flexibility, a simple cam adjustment lets you set 90° pre-travel anywhere within a 180° arc. The steel trip rod, available in lengths to 10", is readily lengthened or shortened by a simple set screw adjustment; can be bent or welded for easy hook-up to other linkages. Correct contact pressure is easily set by a steel spring adjustment insuring split-second contacts, ten times normal switch life. Micro switch unit is fully enclosed for lasting protection against dirt and moisture.

Select from a complete line of National Acme Limit Switches for any control application. Write for Limit Switch Bulletins containing detailed information stating your requirements.

*at 10°

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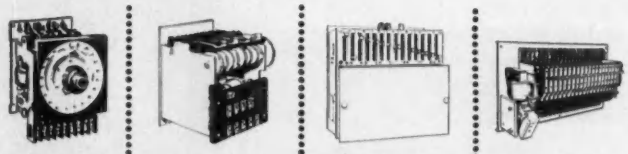
CIRCLE 167 ON READER SERVICE CARD 167

with easy-to-use *EAGLE* CYCL-FLEX reset timers

A highly accurate and dependable easy-to-use timer, designed for mounting in control panels. Sealed dial protects timer when exposed to oil and dust conditions. Timer switches control four load circuits. Interlocking contacts are provided without the use of auxiliary relays. Synchronous motor drive insures accurate timing.

WRITE for descriptive Bulletin 120. Address Dept. CE-1159.

EAGLE HAS 24 TYPES TIME-COUNT CONTROLS



Dial Timers and Counters | Cam Timers | Multi-Circuit Timers | Step Switch

EAGLE SIGNAL COMPANY
A DIVISION OF GAMEWELL COMPANY
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NEW PRODUCTS

able also for channel mounting, this instrument weighs 35 lb and features interchangeable plug-in input chassis. Range is adjustable from 0.9 mv to 0-100 mv. Zero may be set anywhere across the chart. Optional chart speeds range from ⅛ in. per hr. to 8 in. per min. Recording accuracy is within 1 percent of full scale. Available accessories include alarm contacts, retransmitting pots, and event markers on either or both margins.—Varian Associates, Palo Alto, Calif.

Circle No. 285 on reply card

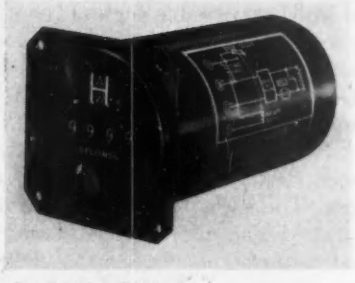
200-CHANNEL ANALYZER

Designed for rapid, accurate spectrum analysis, the Model 34-8 transistorized 200-channel analyzer uses a ferrite core memory system and provides a direct parallel decimal readout. The instrument may also be used as a multichannel scaler.

Characteristics:

Linearity: within 0.5 percent
Average dead time: 60 μsec
Normal capacity: 100,000 counts per channel
—Radiation Instrument Development Laboratory, Inc., Chicago, Ill.

Circle No. 286 on reply card



STOP CLOCKS

Featuring electrical reset to permit local or remote control or automatic operation and digital readout for faster, more accurate reading, a new line of ac and dc stop clocks provides an extremely accurate means for measuring time intervals. The dc version, above, is designed for 20- to 30-volt operation. The ac models are available for both 60- and 400-cycle operation. Applications include the calibration of intervalometers and fire control equipment, production testing of timing devices, and the control of various manufacturing processes.—The A. W. Haydon Co., Waterbury, Conn.

Circle No. 287 on reply card

USE LOTS OF TAPE?

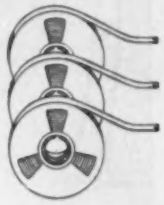
"SCOTCH" BRAND Instrumentation Tapes cut operating costs

Let's develop our own small theory of relativity. For everything's relative, after all—even economy. Clearly, an economy effected now and *corrected* later is no economy at all. In instrumentation tape, there's only one genuine economy—reliable performance. And in performance, the last two words for any acute tape-user are "SCOTCH" BRAND.

First to last, "SCOTCH" BRAND Magnetic Tapes offer uniformity and reliability—born of the experienced 3M technology that created the first practical magnetic tape and continues to advance the art of tape-making day by day.

But let's look at economy from another viewpoint—in terms of some things around the periphery that might not come so readily to mind—storage, use, waste, and time saved.

What other kind of record is so permanent it may last a lifetime, yet requires so little space for storage? Three reels of "SCOTCH" BRAND like those at the right "contain" 30 million characters. What other medium serves input, output and memory functions at such high speeds? Accepts both digital and analogue data?



What other kind of record is not *consumed*, even when it is used? "SCOTCH" BRAND Magnetic Tape is run and rerun for analysis, erased and used again, permits retaping with corrections, editing and new data.

Last, but far from least—in these days when time is money, what other medium speeds up data acquisition, reduction and control programming in a way that keeps critical projects rushing forward at full tilt? Or cuts production lead time and human error to a point where a 1000% saving may be realized?

At any cost, "SCOTCH" BRAND Magnetic Tapes would be a good buy. And in every application, "SCOTCH" BRAND Tapes offer that greater economy—reliability. "SCOTCH" BRAND High Resolution Tapes 158 and 159 let you pack more bits per inch, offer extra play reels. "SCOTCH" BRAND Sandwich Tapes 188 and 189 end rub-off, build-up, cut head wear to an absolute minimum, show little wear in 50,000 computer passes. "SCOTCH" BRAND High Output Tape 128 offers top output at low frequencies, even under ambient temperature extremes. "SCOTCH" BRAND Instrumentation Tapes 108 and 109 offer top performance at lowest cost.

Where there's no margin for error, there's no tape like "SCOTCH" BRAND Magnetic Instrumentation Tape. For details, write Magnetic Products Div., 3M Company, Dept. MBS-119, St. Paul 6, Minn., or mail the reader inquiry card. © 1959 3M Co.

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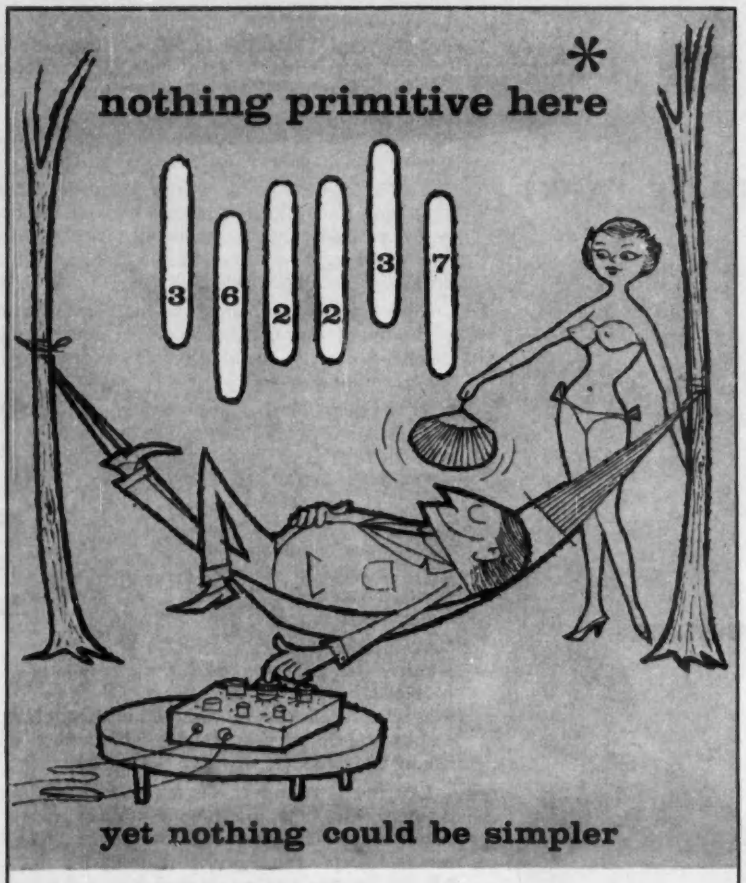
SCOTCH BRAND MAGNETIC TAPE
FOR INSTRUMENTATION

MINNESOTA MINING AND MANUFACTURING COMPANY
. . . WHERE RESEARCH IS THE KEY TO TOMORROW

3M COMPANY



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Generates pre-selected pressures to ±0.05% accuracy

The Series Q3700 — Ideal for

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Selectable pneumatic pressure outputs are precisely controlled to pre-determined values with *digital* accuracy. This *portable* system provides the ultimate in accuracy, simplicity and resolution. For complete information request Product Bulletin 111.

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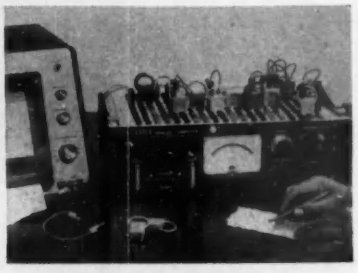
NEW PRODUCTS

PLUS . . .

(288) **H. R. Kirkland Co.**, Morristown, N. J., offers a new type of **lamp annunciator** with rectangular lamp units and momentary contact pushbuttons. . . . (289) A new 90-deg projection-type **digital readout** was recently announced by **Industrial Electronic Engineers, Inc.**, North Hollywood, Calif. . . . (290) The Model 3280 digital **tape transport**, now in production at **Potter Instrument Co.**, Plainview, N. Y., is specifically designed for low speed applications. . . . (291) **Oxford Engineering Co.**, Wellesley Hills, Mass., has introduced an 8-digit, transistorized, **high speed counter** using cold-cathode decade counting tubes.

Circle No. 288, 289, 290, 291 on reply card

RESEARCH, TEST, & DEVELOPMENT



23-POUND COMPUTER

Offered as the world's smallest full-fledged analog computer, this Model 3500 10-amplifier unit will solve a seventh order differential equation or a ninth degree Laplace transform. Aside from its educational applications, the 3500 represents an extremely flexible piece of laboratory test equipment. Suitable patching on the problem board converts the unit to a constant voltage or constant current source, a low frequency signal generator, a precision voltmeter, or a precision instrument for measuring component characteristics. The 23-lb. unit measures 5¼-in. high, 19-in. wide, and 10¼-in. deep and will be available with 1 percent or 0.1 percent computing components, stabilized or unstabilized amplifiers, and a variety of optional accessories. Prices will range from $1200 to $2500.—Donner Scientific Co., Concord, Calif.

Circle 292 on reply card

SQUEEZING HIGH POWER INTO small packages

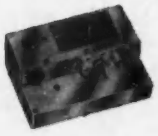
Unhampered by traditional thinking, TELECHROME engineers have developed an entirely new concept in telemetering equipment — unequalled in compactness, ruggedness and dependability.

TELEMETERING TRANSMITTERS

FM/FM or PDM/FM Crystal Controlled

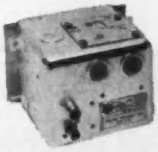
215 to 260 Megacycles

Model 1472



4" x 1.5" x 2.7"
2 Watts

Model 1463

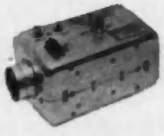


5 1/32" x 3 3/16" x 4"
15 to 30 Watts

Model 1462

6" x 4 1/4" x 3 1/4"
50 to 60 Watts

Model 1468A



6.5" x 4" x 3.29" RF Amplifier
2 watts in — 100 watts out

SUB-CARRIER OSCILLATOR.
Model 800C — 1.9" x 1.9" x 2.45"

Deviation stability ±1% of band width. Deviation linearity less than 1% of band width under all conditions measured from a straight line drawn between end points.

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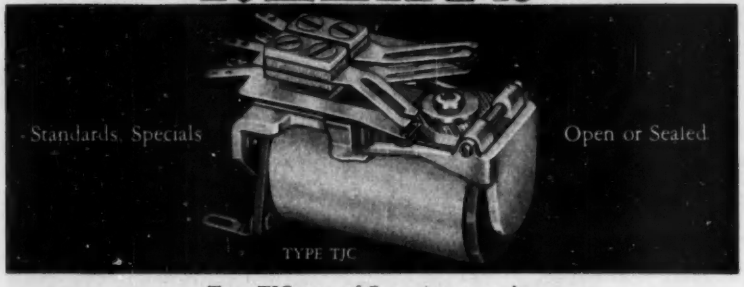
RELAYS



Type TJC, one of Comar's many telephone types, combines features not usually found in a small relay. Lightweight, extra sensitive, large contact spring capacity, hinge-type armature, heavy duty yoke and independent twin contacts are some of its advantages. Inquiries invited.

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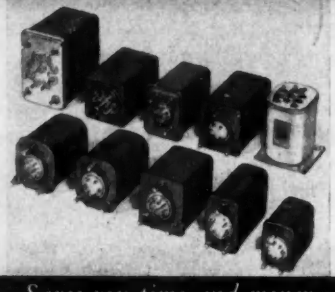

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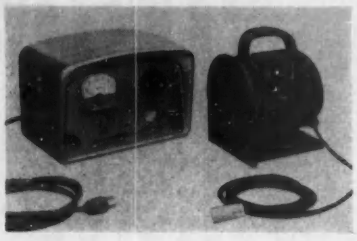
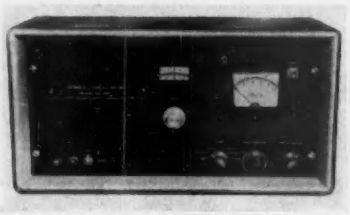
NEW PRODUCTS



CONTROLLED IR SOURCE

Designed to measure the sensitivity of infrared detection and infrared systems or for use as a reference standard to determine remote target temperature and emissivity, a model PE521-4 controlled infrared source operates in conjunction with PE521-5 temperature controller. Radiation element of the source consists of a pure silver core with a conically shaped cavity. A black refractory coating on the walls of the cavity provides a emissivity approaching unity. Power requirement for the source is 160 watts, max; the controller requires 300 watts at 115 volts, 60 cycles.—Perkin-Elmer Corp., Norwalk, Conn.

Circle No. 293 on reply card



WIDE RANGE OSCILLATOR

The Gerber Model GO-20F Oscillator, a wide frequency range instrument, features a 50-ohm output impedance, a Wien bridge stabilized oscillator, excellent stability, low distortion, and continuous control of the output voltage level. Some of its basic applications include circuit development, the testing of a 50-ohm system, signal generators, etc.

Characteristics:

Frequency range: 10 cps to 5 mc
Frequency stability: 1 percent after warm-up
Amplitude stability: 2 percent after warm-up
Output voltage: 2 volts rms, max
Distortion: Less than 2 percent

—The Gerber Scientific Instrument Co., Hartford, Conn.

Circle No. 294 on reply card

Key building block in flexible process control...
the Beckman 123 Data Processing System. ⌘ Use it alone for process data logging and alarming. Use it with a general-purpose computer for computer control. Its flexibility allows you to first study and then control your process...as well as modify process variables and easily reset controls. ⌘ In addition to this flexibility, the 123 Data Processing System offers all-transistorized circuits for maximum dependability... pinboard programming for ease of operation...100 or more channels to handle any logging problem...typewriter, paper tape, or punchcard readout... visual and audio alarms. ⌘ Let a Beckman stream-control specialist help you to a 1-2-3-4 building block solution to your process control needs... from sample handling (1) and stream analysis (2) through data processing (3) and digital computing (4) to an ultimate closed loop. For more information on the 123 Data Processing System or an on-stream survey, write for Data File 46-11-09.

Beckman
Scientific and Process Instruments Division
Beckman Instruments, Inc.
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CIRCLE 173 ON READER SERVICE CARD

NEW !

The 603-607 and the 621 series of direct recording oscillographs, the newest in Midwestern's **EXPANDED** line of precision electronic test data instruments, are the results of years of proven leadership in the field of oscillography. Write for complete brochures and performance information.

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603 & 607 SERIES D/R OSCILLOGRAPHS — 50 traces — 12" record — 20 record speeds (.071 to 173 ips) — 6,000 cps flat response.

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NEW PRODUCTS

TARGET SIMULATOR

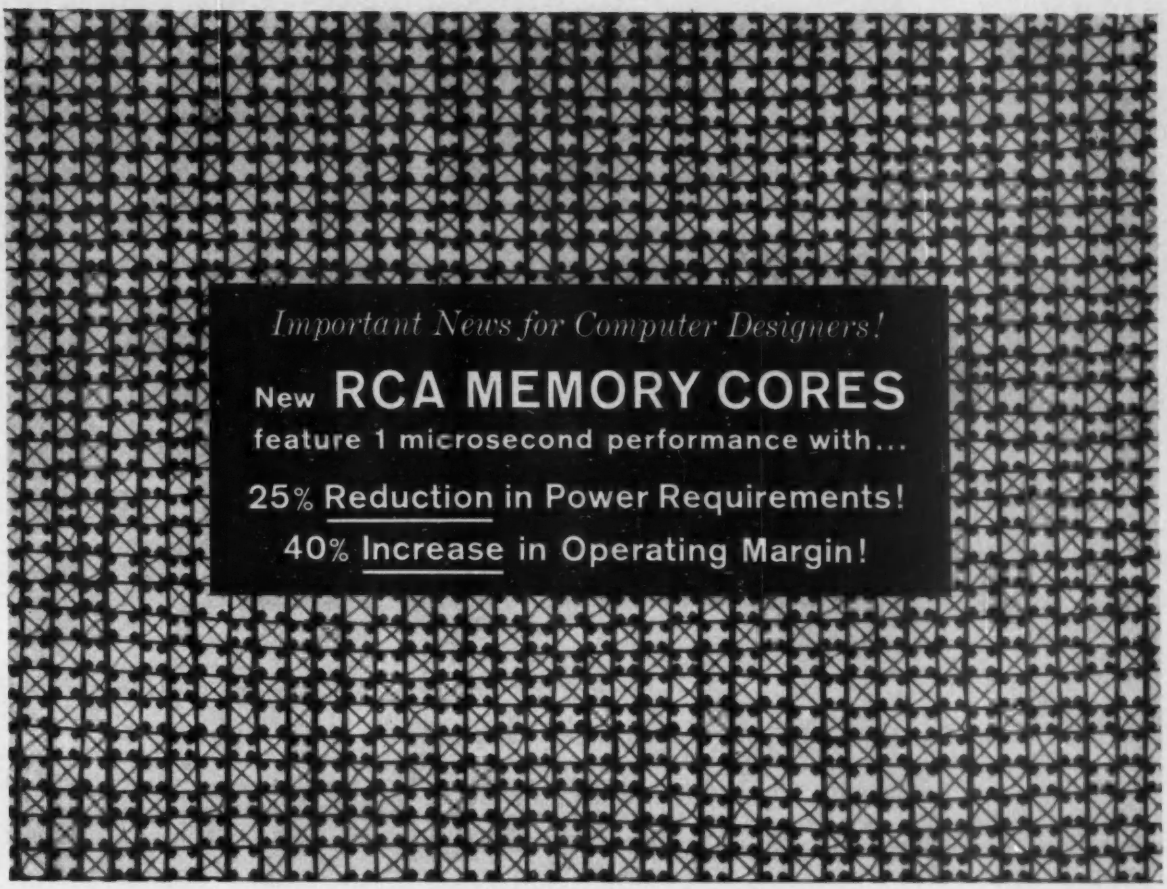
Designed for the training and practice of radar operators, this new target simulator generates azimuth, range, and video information for separate targets which maneuver realistically under the precise control of the operator. Since it does not interfere with normal operation of the radar equipment, both real and synthetic radar returns may be displayed simultaneously. Its X-Y integration programming and unique azimuth gating circuit provide a high degree of realism and accuracy. The unit operates directly from 115-volt, 60-cycle source and requires only three connections to the radar: trigger input, synchro input, and video output. —Philco Corp., Philadelphia, Pa.

Circle No. 295 on reply card

READS PEAK AMPLITUDES

The fully transistorized Model PDV-823 digital voltmeter measures and displays the peak amplitude of a single event, positive-going pulse. It uses an in-line, in-plane digital display. Both decimal and binary-coded decimal electrical outputs are provided. Pulse duration can vary from 0.1 to 2.0 millisec. Unit features plug-in circuitry, contains no stepping switches or relays, and sells for $3,975. —Epsco, Inc., Cambridge, Mass.

Circle No. 296 on reply card


Important News for Computer Designers!
New RCA MEMORY CORES
feature 1 microsecond performance with...
25% Reduction in Power Requirements!
40% Increase in Operating Margin!

Dramatic improvement over present standard cores offers greater design flexibility, top performance in high-speed coincident current memory applications

New 1-μ sec memory cores 226M1 (XF-4028) and 228M1 (XF-4257) developed at RCA's Materials Lab in Needham Heights, Mass., represent an important step forward in ferrite core design for military and commercial computers. See chart for the significant improvements in power requirements and operating margin now possible in 1-μ sec operation.

Call your local RCA Field Representative and learn how the new 226M1 and 228M1 can fit into your new computer designs. He can also give you information on the entire line of RCA Ferrite Memory Cores, Planes and Stacks available to meet your specific design requirements. For technical data, write RCA Commercial Engineering, Section K-56-NN, Somerville, N. J.

NOMINAL OPERATING CHARACTERISTICS AT 25°C

Type	Size	Full Driving Current (Im) (ma)	Partial-Write Current (Ipw) (ma)	Pulse Rise Time (T_r) (μsec)	Switching Time (T_s) (μsec)	Response	
						"Undisturbed 1" (μV_1) (mv)	"Disturbed 0" (dV_d) (mv)
228M1 (XF-4257)	.080" x .050" x .025"	620	310	0.2	1	160	18
226M1 (XF-4028)	.050" x .030" x .015"	380	190	0.2	1	75	10

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AND WANT TO MEASURE
0.1 to 100 millivolts full scale

AND THEN AMPLIFY

CHOOSE THE NEW HONEYWELL D-C AMPLIFIER

AccuData II

wide-band differential all-transistor D-C Amplifier for strain gages and thermocouples

- **Full Scale Input:** Unbalanced: ±100 μv to ±100 mv; Differential: ±3 mv to ±100 mv; Open Loop: Below drift level
- **Full Scale Output:** ±2v at 50 ma, dc to 10 kc
- **Frequency Response:** to 20 kc
- **Output Impedance:** Less than 0.5 ohm at dc on all ranges
- **Input Impedance:** Unbalanced 3 to 100 mv ranges; greater than 20 megohms in parallel with 350 micromicrofarads. Differential: Greater than ± 2 megohms
- **Equivalent D-C Input Drift:** Less than 2 μv/10°F ambient temp change on 0.1 to 30 mv input ranges
- **Equivalent Input Noise:** 4μv peak-to-peak on 100 μv to 300 μv range (0-10 cps). 8μv rms on 10 to 30 mv ranges (0 to 100 kc)
- **Common Mode Rejection:** 200,000 at 60 cps on 3 to 30mv ranges

The new Honeywell AccuData II is a completely transistorized D-C Amplifier designed for use in high accuracy data handling systems as a wide-band pre-amplifier for strain gages and thermocouples. Its output can be fed to electronic or electromechanical analog-to-digital converters and simultaneously recorded on galvanometer oscillographs or magnetic tape. Either differential or single-ended input modes can be selected by an eleven position range switch. This switch changes the gain in three-to-one steps. Intermediate gains with high resolution are provided by a ten-turn potentiometer. Write for AccuData II Bulletin to Minneapolis-Honeywell, Dept. 34, Boston Division, 40 Life Street, Boston 35, Mass.

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176 CIRCLE 176 ON READER SERVICE CARD

NEW PRODUCTS

STORED PROGRAM COMPUTER

SPEC, a new general purpose, stored program digital computer and digital differential analyzer is designed specifically as a laboratory and classroom tool. Its command structure is well suited for teaching basic programming techniques. Word length, memory capacity, and operations codes are small enough to permit students to readily grasp the entire logic of the system, yet large enough to provide the programmer with a respectable tool on which to sharpen his talents. For serious computation, it serves as a stored program, single address machine with 128 words of fast access internal storage. A simple change of panels converts the unit from general purpose computer to a digital differential analyzer containing 20 integrators. —Computer Control Co., Los Angeles, Calif.

Circle No. 297 on reply card

PLUS . . .

(298) **Leeds & Northrop Co.**, Philadelphia, Pa., has developed a streamlined precision **wheatstone bridge** of exceptional accuracy. . . . (299) A compact **telemetry calibrator,** recently placed on the market by the **Ramo-Wooldridge Div.** of Thompson Ramo Wooldridge, Inc., Los Angeles, Calif., features 18 IRIG channels and an accuracy within 0.01 percent. . . . (300) The **EZ indicator,** an instrument designed to locate the electrical zero of synchros and resolvers without switching component leads, is now available from **Theta Instrument Corp.**, East Paterson, N. J.

Circle 298, 299 or 300 on reply card

CONTROLLERS, SWITCHES, & RELAYS

PRESSURE SWITCHES

The model 419 hermetically sealed pressure switch, available in three design configurations, is suitable for use in hydraulic fluids, fuels, and other liquids or gases. Weighing ¼ oz and measuring approximately 5/16 in. in diam by ½ in. long, the device may be mounted directly on pressure fitting or built into pressure fitting hardware. Its spst normally-closed switch, rated at 28 vdc, will handle a 100-ma induc-

ALERT . . . key to preparedness . . . job of Martin Activation: The opportunity for REAL engineers and technicians to solve tough problems and apply their specialties to an organized program in missile base operation. The rewards: ground floor opportunities for unlimited professional advancement. Direct all resumes of qualifications to: Dean Pearson, Director of Engineering Staffing, (Dept. 1), Martin-Activation, P. O. Box 2371, Denver, Colorado.

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WEAPONS SYSTEMS MAINTENANCE
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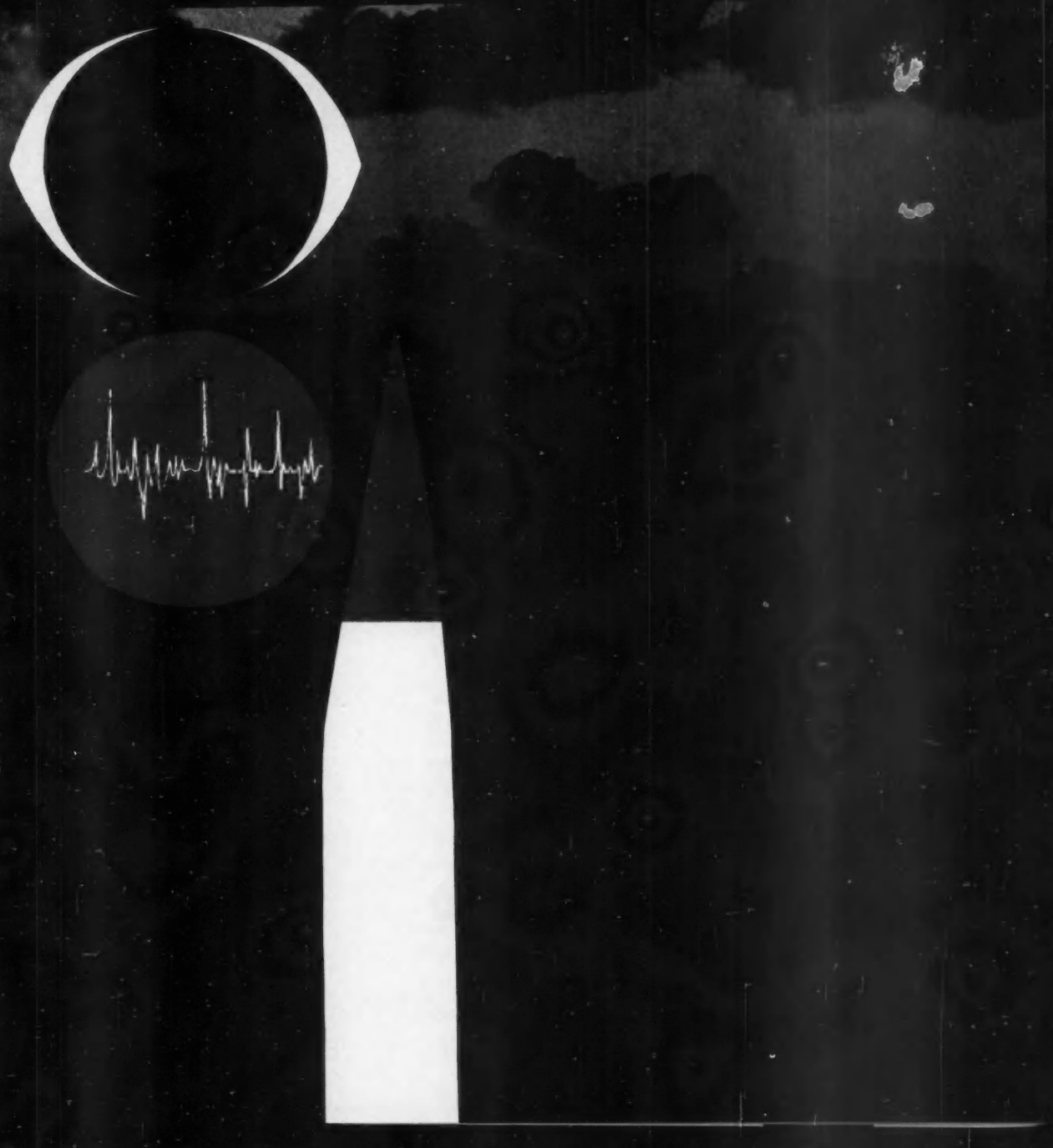
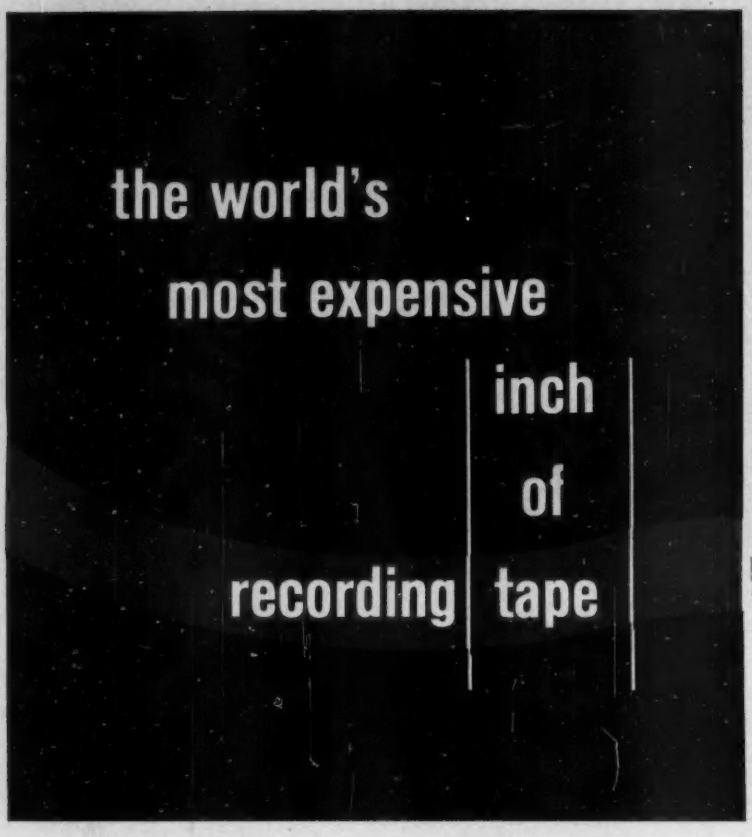
ACTIVATION





There's no question about it—if there were a dropout in this inch of tape it could cost you plenty. That's why our customers invariably demand perfection from our EP Audiotape —the *extra precision* magnetic recording tape for computers, automation, telemetry and seismography.

Audio Devices' battery of Automatic Certifiers is one of the unique means used to make sure EP Audiotape always meets customers specifications. The Automatic Certifier records and plays back every inch of the EP Audiotape under test. These tests can be so demanding that if the tape fails to reproduce just *one* test pulse out of the 40 million put on a single reel, the entire reel is rejected. There are no *if's, and's,* or *but's.*

This is just one of many special quality-control operations. From raw material to hermetically sealed containers, every reel of EP Audiotape gets individual attention.

For more information write for free Bulletin T112A. Write Dept. TC, Audio Devices, Inc., 444 Madison Avenue, New York 22, N. Y.

TYPE EP audiotape TRADE MARK

AUDIO DEVICES, INC.
444 Madison Ave., N. Y. 22, N. Y.
In Hollywood: 840 N. Fairfax Ave.
In Chicago: 5428 Milwaukee Ave.
Export Dept.: 13 East 40th St., N. Y., 16
Rectifier Division: 620 E. Dyer Rd., Santa Ana, Calif.

NEW PRODUCTS

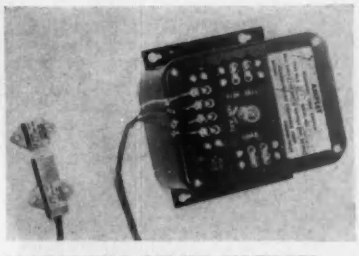
tive or 200-ma resistive load. Actuating pressures range from 1 to 500 psi. Device meets Mil-E-005272 B, Procedure 1 specifications for vibration, shock, acceleration, and humidity.—Bourns, Inc., Riverside, Calif.

Circle No. 301 on reply card

ONE MOVING PART

The Pressurmite, an absolute pressure switch designed to actuate control and warning systems, should find wide application in the aircraft, missile, and industrial control fields. Pressure required to open or close an electrical circuit may be set anywhere from 2 to 14.7 psia. Contact current rating depends on application.—Friez Instrument Div., Bendix Aviation Corp., Baltimore, Md.

Circle No. 302 on reply card



MAGNETIC LIMIT SWITCH

The Amplet magnetic limit switch, shown above, consists of three parts: a probe, which is normally mounted on a stationary part on the machine being controlled; a magnetic trigger, mounted on a moving machine member; and a power amplifier, which increases the power output of the probe to useful levels. Snap-action response time of the unit requires less than 1 millisec. Distance at which control action takes place can be varied from 0.020 to 0.2 in. At full load, the de-

FILLING THE VOID

in practical process control

GENESYS

Now, you can optimize your process even if process dynamics are unknown! Custom designed for process control, the Genesys Digital Computer Control System is commercially practical . . . uses your existing instrumentation to control, analyze and optimize . . . delivers unmatched reliability with operational simplicity. Genesys Systems assure 4,000 hours (six months) of continuous onstream operation between scheduled maintenance periods. And your present operators get maximum performance from a Genesys with a minimum of training. Evaluate Genesys before you invest in process or pipeline automation programs. Compare the many exclusive advantages and unprecedented economies offered by the Genesys Digital Computer Control System. Write today for "Evolution in Process Control."

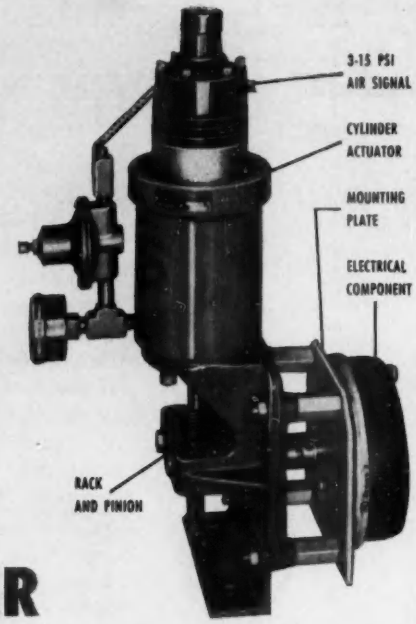
Seven giant steps forward in practical digital control, the UMP (Unit Memory Processor) was designed specifically for process and pipeline control, uses the best combination of digital equipment with practical speed matched to the problem.

GENESYS CORPORATION

10131 NATIONAL BLVD., LOS ANGELES 34, CALIFORNIA

A Subsidiary of CHANCE VOUGHT

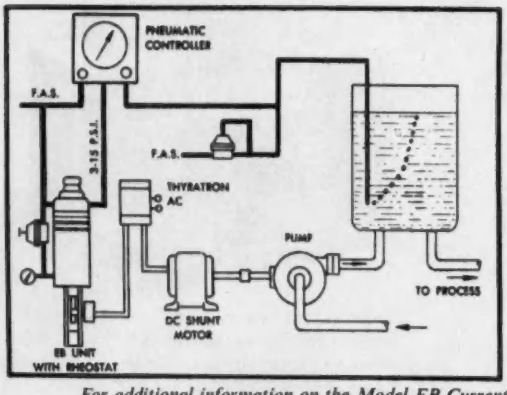
ELECTRIC CONTROL FROM A PNEUMATIC SIGNAL WITH THE CONOFLOW MODEL EB CURRENT CONTROLLER



The Model EB Current Controller—an exclusive product of Conoflow Corporation—is a unique final control element. It is a pneumatic-electric transducer consisting of a pneumatic cylinder actuator fitted with a rack and pinion mechanism, and a standard electrical component such as a rheostat, potentiometer or autotransformer. The cylinder actuator, operating from a 3-15 psi air signal, produces a rotary motion (to 360°) to precisely position the electrical device affording automatic control of voltage, current, inductance, capacitance, resistance, or other electrical values.

APPLICATIONS—Conoflow Model EB Current Controllers are available from the factory in over 200 combinations of electrical components to handle a wide variety of applications. A few of these include:

- **Constant Pressure**
- **Proportional Flow**
- **Liquid Level**
- **Temperature Control**
- **Machine Tool Speed**
- **Conveyor Control**
- **Heat Treating**
- **Humidity Control**



A TYPICAL EXAMPLE

Direct flow regulation by varying pump speed is accomplished when the EB unit is used with a pneumatic controller and an electronic speed changer. It automatically positions the small rheostat in the grid circuit of a thyratron controlled speed changer, thereby adjusting motor and pump speed. This method of flow rate control can be used to provide control of temperature, pressure, pH, interface, or liquid level. It eliminates the valve, reduces motor power input, and provides for positive flow rangeability.

The EB unit with cylinder directly coupled to the armature or field rheostat of a DC shunt wound motor is also widely used for motor speed control.

For additional information on the Model EB Current Controller write to Conoflow Corporation, 2100 Arch Street, Philadelphia 3, Pa., for Bulletin EB-3A.

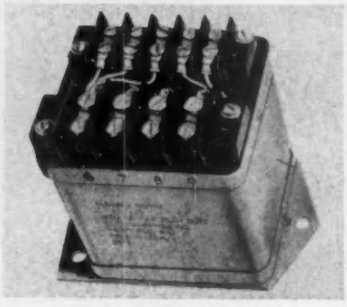
CC-804

Conotrols® CONOFLOW CORPORATION FOREMOST IN FINAL CONTROL ELEMENTS SUBSIDIARY OF WALWORTH

NEW PRODUCTS

vice draws 7 watts of 115 vac input power. Output signal is 50 μa in the "off" condition and 5 watts at 24 vdc in the "on" condition.—Consolidated Controls Corp., Bethel, Conn.

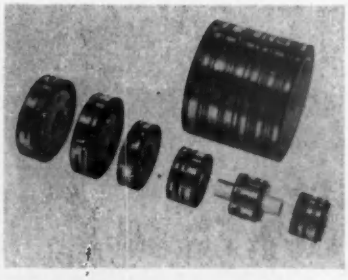
Circle No. 303 on reply card



THERMISTOR CONTROL

Components of this direct monitoring overtemperature device include a magnetic relay, two transistor amplifiers, a diode network for signal separation, and a voltage regulated power supply. Though specifically designed to protect 3-phase ac motors, it is suitable for use wherever overtemperature is a problem. A thermistor inserted in the windings of the motor, generator, transformer, or other equipment assures response only to the actual temperature of this equipment. Relay contacts are of the pilot duty type and are rated at 600 vac.—Cutler-Hammer, Inc., Milwaukee, Wis.

Circle No. 304 on reply card



HIGH SPEED SWITCHES

A new line of rotary switches, designed for use in missiles and aircraft, features shaft speeds as high as 1,000 rpm. Similar in principle to the company's analog-digital converters, these switches consist primarily of a bearing mounted cylinder and shaft assembly. The cylinders, as shown in the photo above, are divided into conducting and nonconducting segments.

KOLLMORGEN Instruments and Systems for underwater viewing

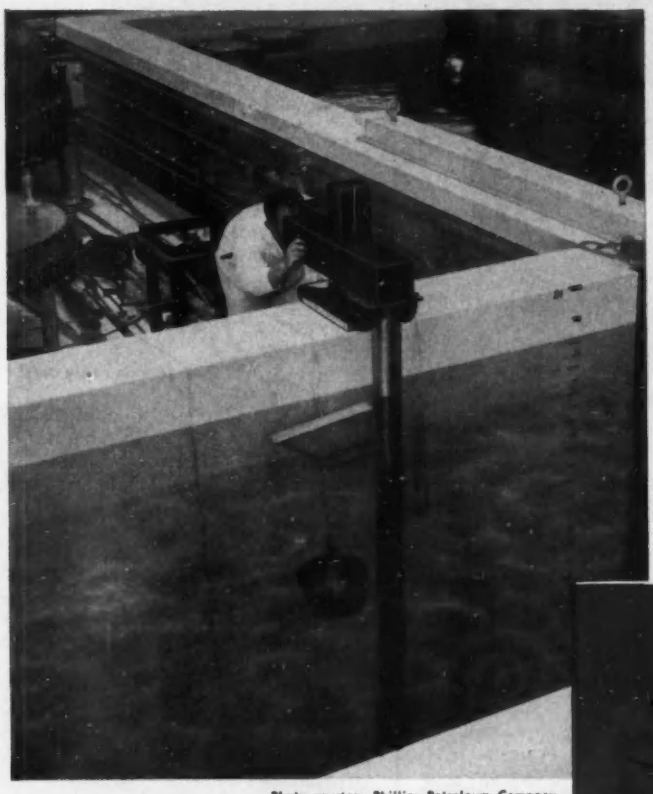


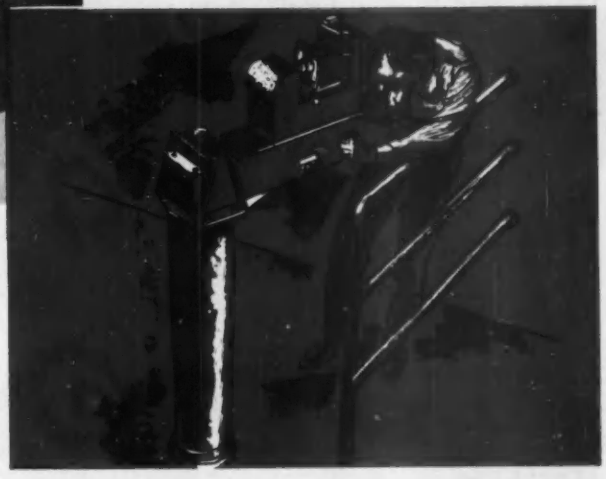
Photo courtesy Phillips Petroleum Company

At the National Reactor Testing Station, a Phillips Petroleum Company technician inspects radioactive materials through a Kollmorgen Underwater Periscope. The instrument is mounted on the edge of the working canal which abuts the Engineering Test Reactor.

Kollmorgen designs and manufactures optical, mechanical and electronic instruments and systems for remote viewing, inspection, testing and photography. The machine tool, chemical process, atomic energy, missile, oil and pipe line, electronic and motion picture industries exemplify the variety of fields which Kollmorgen serves.

If you face a remote viewing problem it may be that a standard Kollmorgen instrument can help solve it. If not, our engineering department can design a special instrument to meet your needs. A procurement sketch with brief description of the problem is sufficient to start.

A new twenty-four page illustrated brochure describes our facilities and products. You may have a copy by writing Dept. 21N.



Most major atomic installations use Kollmorgen Remote Viewing Equipment. At the Shippingport Reactor, a Kollmorgen Periscope similar to the one shown (right) is used for inspecting fuel elements. The instrument is equipped for photography of radioactive material.

for internal inspection

Zeiss-Kollmorgen Borescopes are versatile devices for the internal inspection of tubing, long bores, engines, aircraft structures, etc. They are self-illuminating. Diameters from .100", lengths to 45 feet or longer.

KOLLMORGEN
optical corporation
NORTHAMPTON, MASSACHUSETTS

CIRCLE 181 ON READER SERVICE CARD 181

FAIRCHILD TA-400 ACCELEROMETER SMALLEST EVER MADE

high shock and vibration resistance...
0.5% accuracy...self-torquing for system testing.*

This hermetically sealed linear accelerometer for missile and aircraft applications has an extremely sensitive differential transformer pick-off. It will measure accelerations from ¼g to 50g. Viscous fluid damping is provided over a wide temperature range. *The pick-off is wired with additional taps to allow a DC or AC excitation (Filterable from pick-off excitation) to be superimposed. This torques the restrained pendulum in either direction from null.

FAIRCHILD CONTROLS CORPORATION
COMPONENTS DIVISION
225 Park Ave., Hicksville, L. I., N. Y. ; 6111 E. Washington Blvd., Los Angeles, Cal.

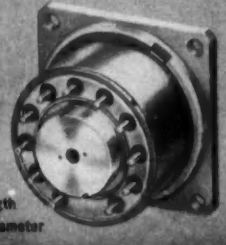
GYROS
PRESSURE TRANSDUCERS
POTENTIOMETERS
ACCELEROMETERS

A Subsidiary of Fairchild Camera and Instrument Corporation

WRITE TO DEPT 35C

SHOCK: 100G EACH OF THREE AXES

VIBRATION: 20G TO 2000 CPS EACH OF THREE AXES



⅛" Length
1/16" Diameter

General Characteristics

Range	±¼g to ±50g
Undamped natural frequency	10-175 cps
Output	Differential Transformer 6 volts into a 10K load. 400 cps phase sensitive
Null	15 to 50 MV
Accuracy	Including linearity, hysteresis, and repeatability after light tapping—0.5% of full scale to half scale.

NEW PRODUCTS

Multiple conductor "broom" type brushes ride on each track of the cylinder. Number of tracks and segmentation of each depends on the number of circuits and type of sequencing required. For example, the Model P-1280-11A features two segmented switching tracks and a continuous track for a common input. Mechanical accuracy of its segments is within 1 deg. Its current capacity, 50 ma at 28 volts per brush, makes it suitable for use with sensitive relays and solid-state switching circuits.—Kearfott Co. Inc., Clifton, N. J.

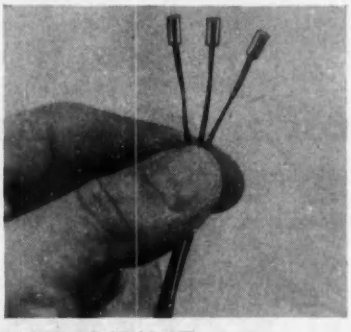
Circle No. 305 on reply card

PLUS . . .

(306) **Chicago Telephone Supply Corp.**, Elkhart, Ind., offers two new 13/16-in. diam **push-pull switches** featuring actuating forces as low as 6 oz. . . . (307) Development of a **close differential relay** with a dpdt contact arrangement rated at 3 amp has been reported by **Guardian Electric Mfg. Co.**, Chicago, Ill. . . . (308) A new **motor-driven switch**, introduced by **Kinetics Corp.**, Solana Beach, Calif., is 43 lb. lighter than its predecessor and is designed for use in the Series D Atlas missile.

Circle No. 306, 307, or 308 on reply card

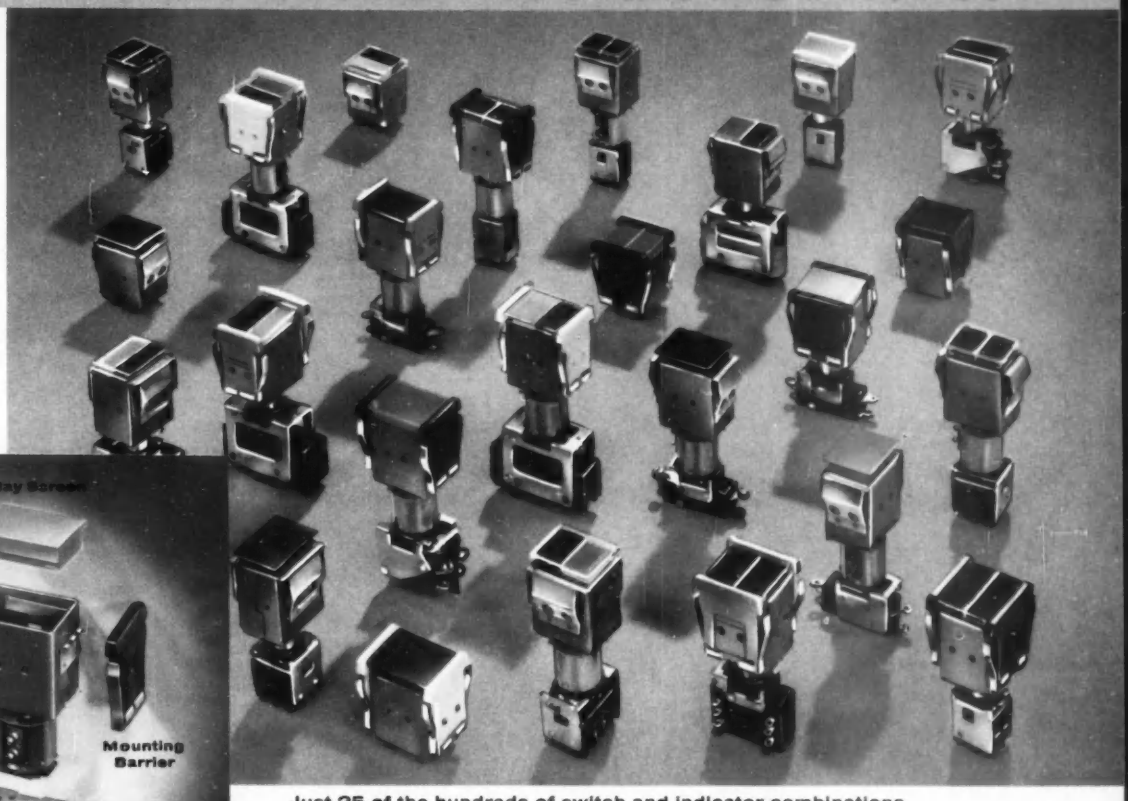
PRIMARY ELEMENTS & TRANSDUCERS



RAPID RESPONSE

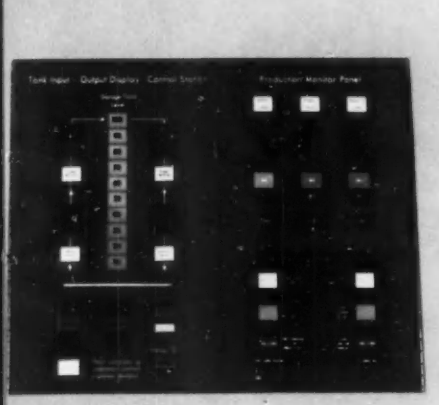
Photo illustrates the tiny Model S-22 high temperature resistance thermometer. This device contains a small platinum sensing element and provides reliable operation and rapid response to transients and temperature

MICRO SWITCH Precision Switches



Just 25 of the hundreds of switch and indicator combinations

Modular concept allows wide choice of combinations. Parts snap together and into panels without tools.



Four Series 2 mounting types permit mounting singly or in columns or rows, provide panel design freedom.

Build your own lighted pushbutton switches and indicators with Series 2 modules

No tools are needed to put together Series 2 modular assemblies that provide a choice of hundreds of different control and display functions.

From our Catalog 67, you select modules from 48 different operator-indicator units, 12 indicators, 18 switch units, 16 mounting barriers differing in size and color, 40 color display screens, and 4 filters.

Up to 4 lamps in each Series 2 indicator module provide improved signal reliability, and choice of transmitted or projected signal color.

Catalog 67 describes Series 2 devices and switching units in detail . . . contains helpful information and application data for human factors engineers and for electrical engineers. Catalog 67 and application assistance are available on request from the MICRO SWITCH branch office near you. Or write for your copy.

MICRO SWITCH . . . FREEPORT, ILLINOIS
A division of Honeywell
In Canada: Honeywell Controls Limited, Toronto 17, Ontario

Honeywell
MICRO SWITCH Precision Switches

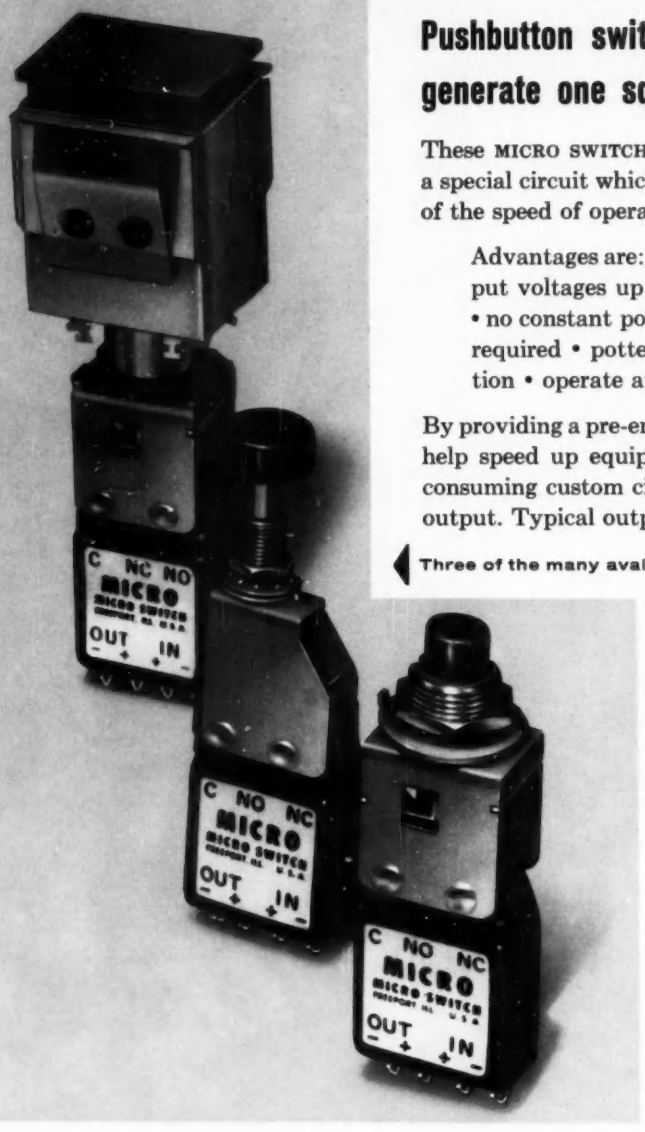
MICRO SWITCH Precision Switches

Pushbutton switches with built-in "One-Shot" circuit generate one square pulse per operation

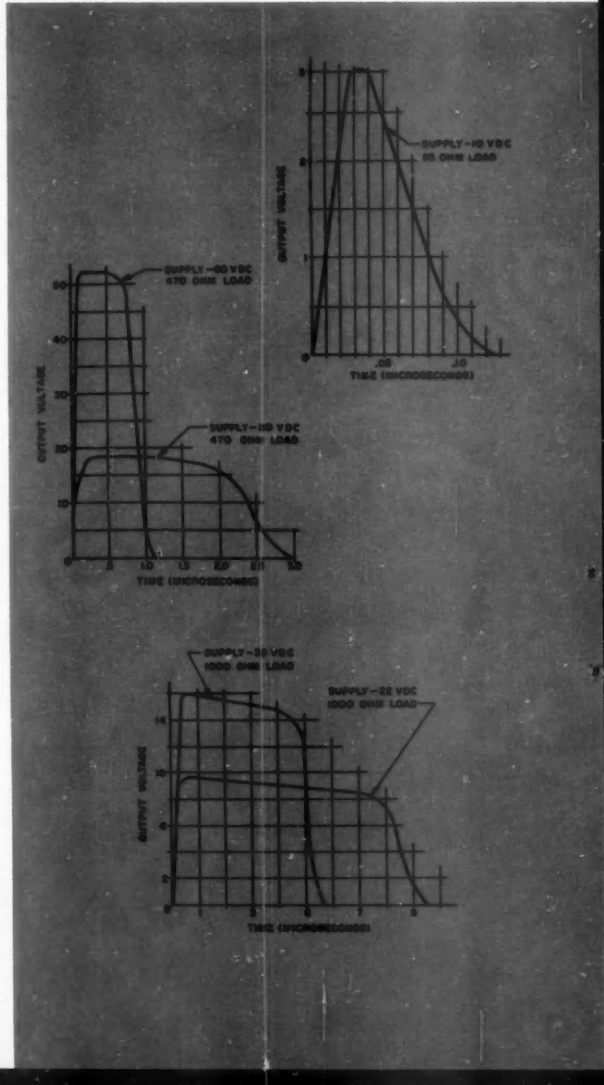
These MICRO SWITCH snap-action pushbutton assemblies incorporate a special circuit which produces a single square wave pulse, regardless of the speed of operation.

Advantages are: pulse widths from 0.1 to 10.0 microseconds • output voltages up to 180 volts • can drive loads as low as 5 ohms • no constant power drain • produce positive or negative pulse, as required • potted circuit for physical and environmental protection • operate at temperatures from —65° to +185° F.

By providing a pre-engineered, compact package, "One-Shot" switches help speed up equipment design by eliminating the need for time-consuming custom circuit development to accomplish a shaped wave output. Typical output curves are illustrated below:



Three of the many available "One-Shot" switch assemblies



The "One-Shot" switch can be supplied as an integral unit with any MICRO SWITCH pushbutton device. Applications include computer and radar consoles, keyboards, electronic test equipment, checking ring counters, setting and resetting flip-flops, and reflected pulse systems. Ask for data sheet 150.

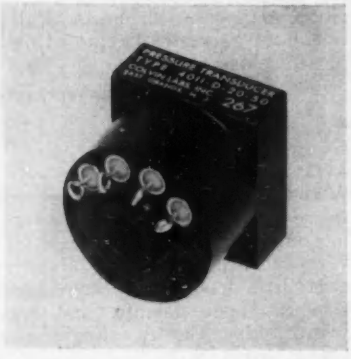
Engineering assistance on switch application is available from the MICRO SWITCH branch office near you. Consult the Yellow Pages.

MICRO SWITCH . . . FREEPORT, ILLINOIS
A division of Honeywell
In Canada: Honeywell Controls Limited, Toronto 17, Ontario

Honeywell
MICRO SWITCH Precision Switches

changes within the range of minus 100 to plus 500 deg F. Lead wire attachment will withstand a pull of at least 5 lbs. Calibration accuracies within ¼, ½, or 1 percent may be specified.—Minco Products, Inc., Minneapolis, Minn.

Circle No. 309 on reply card



COMPACT PRESSURE PICK-UP

Just 1-in. sq by 1-in. long, this tiny Series 401 pressure transducer contains a diaphram capsule which actuates the wiper arm of a precision pot. Units are available with pressure ranges of from 0-5 to 0-400 psi, absolute, differential, or gage. Phenomenal pot resistances range from 2,000 to 10,000 ohms. Because these units are insensitive to vibrations of plus or minus 35g, at frequencies to 5,000 cps, they are ideally suited for aircraft and missile applications.—Colvin Labs, East Orange, N. J.

Circle No. 310 on reply card

SHAFT-ANGLE ENCODER

To eliminate the problem of limited space at the point of measurement this Model DV-13D shaft-angle encoder has been designed in two separate packages. These consist of a 25-cu in. optical-mechanical converter and a 37-cu in. amplifier assembly. A

Gas sampling systems tailor-made for your application

No single gas sampling system can possibly handle all applications. Therefore, Hays provides eight groups of proven components which can be assembled in approximately 16,000 different combinations . . . one of which will provide the best possible answer to your particular gas sampling problem.

Hays' trained application engineers will gladly provide assistance in selecting the system tailor-made for you. The complete story is covered in our new bulletin, B651. Write today for your copy.

Automatic Combustion Control
Boiler Panels • CO_2 Recorders
Veriflow Meters and Veritrol
Gas Analyzers • Draft Gages
Combustion Test Sets
Electronic Oxygen Recorders
Electronic Flowmeters
Electronic Feed Water Controls
Miniature Remote Indicators

THE hays CORPORATION

MICHIGAN CITY 37, INDIANA

COMPACT, 3-OUNCE TIME DELAY RELAY

with silicone-controlled delay from 1/4 to 120 seconds

Worth a closer look . . . the Heinemann Type A Silic-O-Netic Relay. Despite its small overall size, the relay offers many big performance features.

For example, double-pole, double-throw switching . . . at fast snap-action contact speed.

The relay is a load carrier in itself: it may be energized continuously . . . does not require auxiliary lock-in circuits.

And it has a hermetically sealed time element that is forever free from the effects of aging or fatigue. The Type A Relay has proven itself in countless applications; it will give you reliable service over a long, long operational life.

For full details, refer to Bulletin T-5002. A copy will be sent on request.

BRIEF SPECS

Time Delays: from 1/4 to 120 seconds

Overall Dimensions: 2-1/16" x 2" x 1-9/16"

Contact Capacity: 3 amps at 120V AC, 1.5 amps at 240V AC (non-inductive load), 1 amp at 50V DC, 0.5 amp at 125V DC.

HEINEMANN

ELECTRIC COMPANY

162 Plum St., Trenton 2, N. J.

S.A. 1078

NEW PRODUCTS

3-ft cable carries 13-digit reading signals from the converter head at the point of measurement to 13 separate amplitude channels. Angle reading is performed at a rate of 100 complete digital words per sec, and is accurate to within 2.5 min of arc. The separately packaged reading head contains a built-in calibration cell for monitoring encoder operation and for precision mechanical alignment at the time of assembly.–Dychro Corp., Newton, Mass.

Circle No. 311 on reply card

LOX THERMISTORS

A new line of bead and probe type thermistors for liquid gas temperature measurements is now in production. Glass enclosed, they are not subject to electrolytic action, and feature rapid response, high stability, and high sensitivity. – Victory Engineering Corp., Union, N. J.

Circle No. 312 on reply card

LIGHTWEIGHT PICKUP

Stainless steel construction of a new miniature airborne pressure transducer pickup permits measurement of pressures up to 1000 psi in corrosive fluids and gas pressures. An extremely small pressure cavity and a NI-Span-C proving ring measuring element assure fast, accurate response to dynamic pressures. The ring also provides a heat sink for the normal heating and resistance gages and a conduction path to the instrument case.

Characteristics:

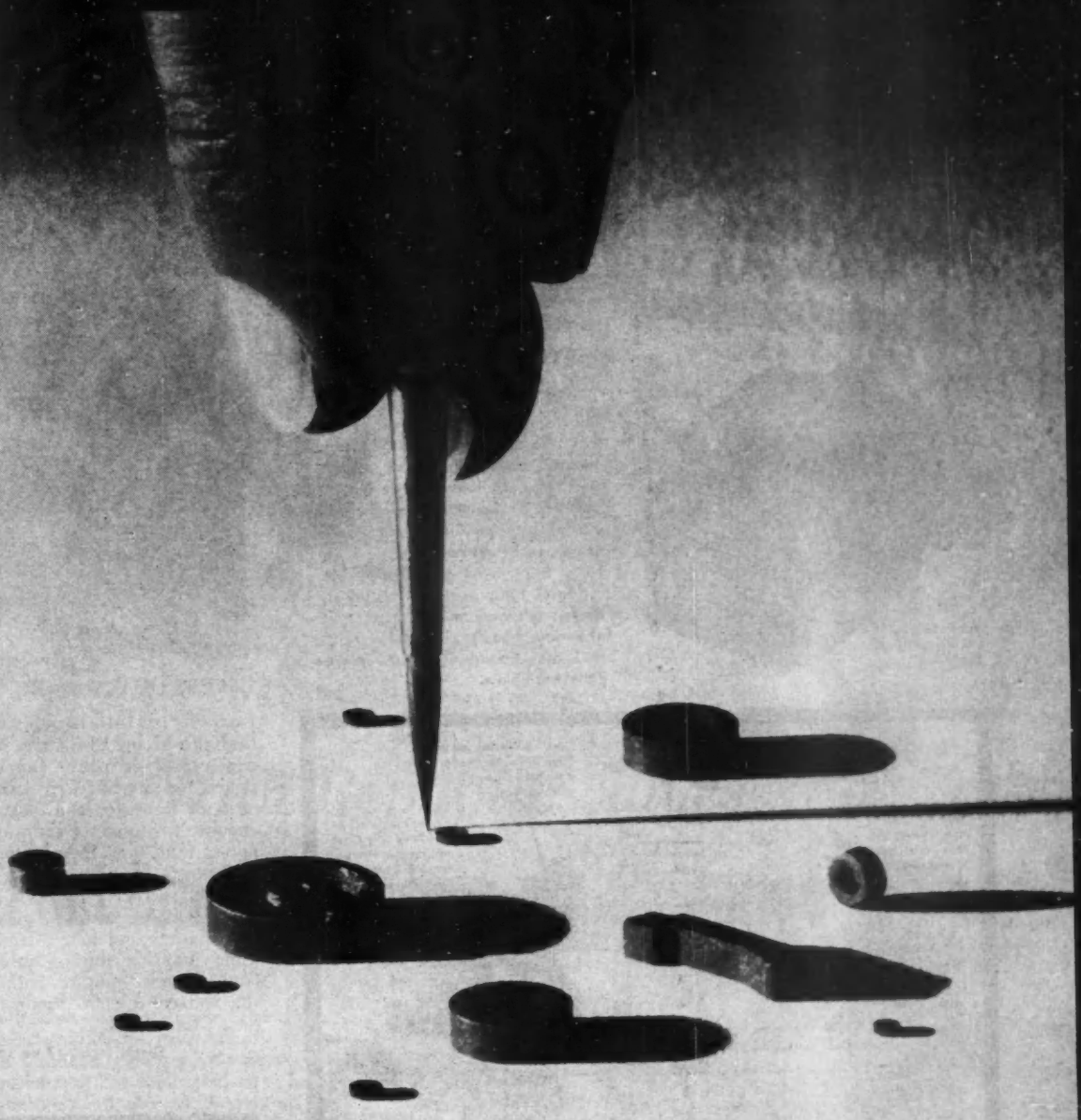
Linearity: Within 0.3 percent
Hysteresis: Within 0.25 percent
Repeatability: 0.1 percent
Overall length: 3½ in.
Weight: 10 oz

–Taber Instrument Corp., North Tonawanda, N. Y.

Circle No. 313 on reply card

PLUS . . .

(314) **Arthur C. Ruge Associates, Inc.,** Hudson, N. H., has developed a new series of **resistance probes** to measure the temperature of noncorrosive gases or dry chemicals up to 800 deg F. . . . (315) A new ultrasonic method for continuous and precise **measurement of liquid level** was announced recently by General **Ultrasonics Co.,** Bloomfield, Conn. . . . (316) Rugged **shaft position-to-digital converters,** in-



CONSIDER...

Products shown are twice actual size

Lockheed for electronic ceramics

The research, development and manufacture of miniature electronic ceramic components is centered in the new Electronic Ceramics Laboratory at Lockheed Electronics and Avionics Division (LEAD).

This facility is fully able to provide electronic ceramics to meet your particular specifications: MEMORY CORES, a whole family of square loop cores to suit computer and shift register applications: MULTI-APERTURE DEVICES (MAD), Cavitron equipment for the volume production of any geometry of MAD; RECORDING HEADS, of very dense materials with high flux density ground to a micro-finish; GARNETS, poly-crystalline yttrium-iron garnets with minimum line width and loss tangent; ALUMINA SUBSTRATES, of high mechanical strength, high electrical resistivity and low dielectric loss; CUP CORES, in any size to specified inductance and minimum temperature coefficient; HIGH "Q" MATERIALS, for use as inductors, tuning slugs, transformers—frequency ranges from 1 to 50 megacycles.

What are your requirements? Write... Marketing Branch, 6201 E. Randolph Street, Los Angeles 22, California. Telephone OVerbrook 5-7070.

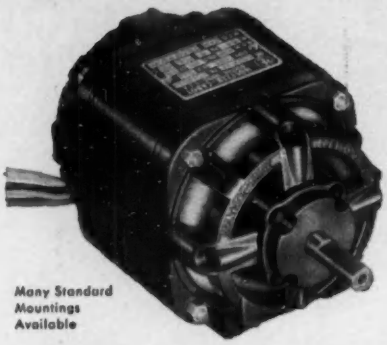
Look to Lockheed for LEADership *in Electronics*

LOCKHEED ELECTRONICS & AVIONICS DIVISION

Requirements exist for staff and supervisory engineers

CIRCLE 187 ON READER SERVICE CARD

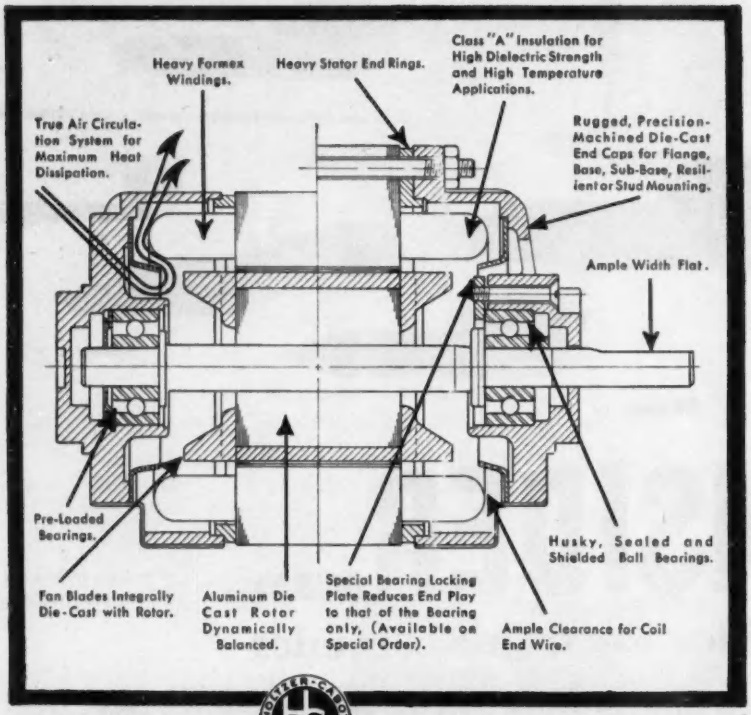
Instrumentation Motors from HOLTZER-CABOT



Many Standard Mountings Available

TYPE R-29 MOTOR
2⅞" Diameter

This motor is an ideal power source for recording instruments, timers, medical instruments, office equipment, blowers, tape recorders, communications equipment, etc. It is available in both 2-pole and 4-pole design, each in three stacking lengths. Type R-29 is a permanent split capacitor type available as an induction or synchronous motor. H.P. of various models ranges from 1/75 to 1/30. Construction features are indicated below.


Heavy Formex Windings.
Heavy Stator End Rings.
Class "A" Insulation for High Dielectric Strength and High Temperature Applications.
True Air Circulation System for Maximum Heat Dissipation.
Rugged, Precision-Machined Die-Cast End Caps for Flange, Base, Sub-Base, Resilient or Stud Mounting.
Ample Width Flat.
Pre-Loaded Bearings.
Husky, Sealed and Shielded Ball Bearings.
Fan Blades Integrally Die-Cast with Rotor.
Aluminum Die Cast Rotor Dynamically Balanced.
Special Bearing Locking Plate Reduces End Play to that of the Bearing only, (Available on Special Order).
Ample Clearance for Coil End Wire.

For more information, write, or use Readers' Service Card.

Sales — Service Representatives in Principal Cities throughout the World

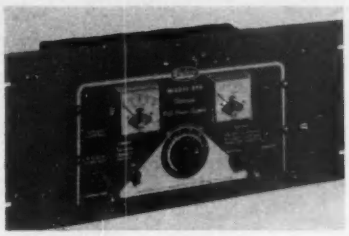
HOLTZER-CABOT MOTOR DIVISION
NATIONAL PNEUMATIC CO., INC.
125 Amory Street, Boston, Massachusetts

Designers and manufacturers of mechanical, pneumatic, hydraulic, electric and electronic equipment and systems

troduced by Kearfott Co., Inc., Clifton, N. J., are designed for extreme environments associated with missile applications.

Circle No. 314, 315, or 316 on reply card

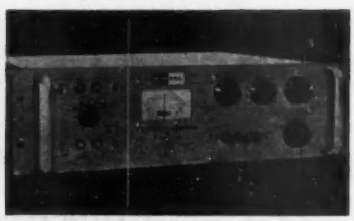
POWER SUPPLIES



OFFERS DUAL RANGE

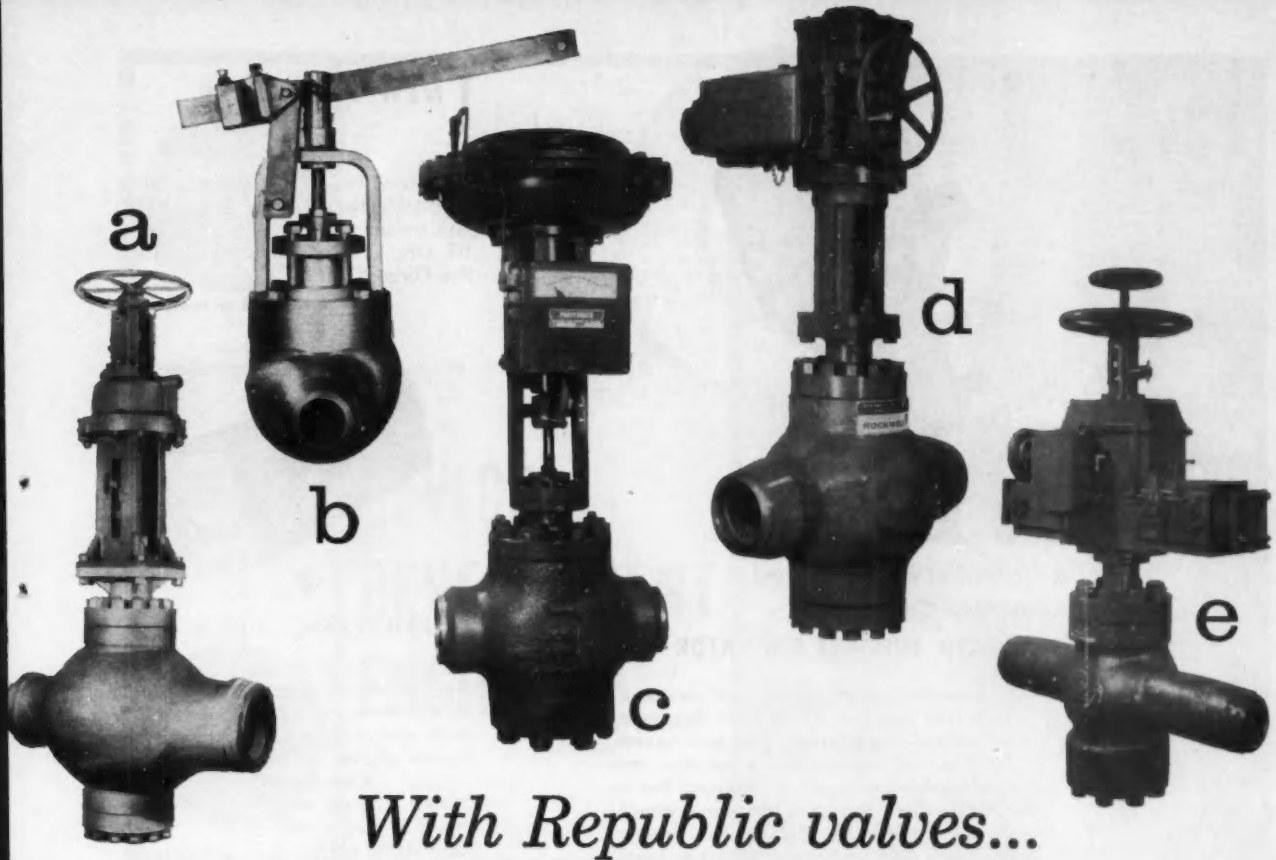
Featuring less than 10 mv ripple at top load, this Model EFBR rack mounted, dual range, dc power supply is designed for servicing and development of both transistor and vacuum tube circuits. It supplies a continuous output of from 0 to 16 volts for current loads up to 8 amps, 0 to 32 volts for current loads to 4 amps. A patented cooling system provides a greater margin of safety and longer rectifier life, while lowering the operating costs. Panel meters indicate both current and voltage.–Electro Products Labs., Inc., Chicago, Ill.

Circle No. 317 on reply card



VOLTMETER–DC SUPPLY

Designated Model 301, this instrument is actually a highly accrate dc voltmeter that doubles as a secondary standard dc power supply. As a null voltmeter it will measure from 1 to 501 volts full scale with an absolute accuracy within 0.02 percent. When used as a dc power supply, the instrument will furnish an output of from 1 to 501 volts at up to 20 ma. Three-decade switch and a potentiometer facilitate setting for both applications.



With Republic valves...

You get longer life, less maintenance

For over 35 years Republic valve developments have paced the changing demands for more sturdy valves by the most progressive utilities and industries. For such services as pump recirculation control, feedwater regulation, steam pressure reducing and high pressure water control, Republic valves have established a reputation for durability, long life and trouble-free performance.

Superior valve design—Republic research into the causes of valve noise and vibration, and also the wear resisting and galling properties of materials has resulted in a modern line of Republic valves of advanced design. Republic valve contours are designed to produce not only the desired regulating characteristics but also to reduce erosion damage and noise as well. Extra large guide bushings, extra deep stuffing boxes, solid plug inner valve construction, plus precise manufacture and long-life materials make Republic regulating valves perform better, last longer, with less maintenance.

Wide selection of valves and features—Rockwell-built Republic regulating valves shown on this page are representative of the complete Republic line:

a. **Cylinder operated valve**
b. **Lever operated valve**
c. **Diaphragm operated valve**
d. **Motor operated valve**
e. **Toggle head operated valve**
f. **Diaphragm operated angle valve**

And, for many special applications, such Republic accessories as pneumatic and electric valve positioners for hysteresis-free control, and a complete line of controllers are available.

Whatever your regulating valve problem, let Republic engineers put their years of application experience to work for you. For additional information, see your Republic representative, or write to Republic Flow Meters Company, 2240 Diversey Parkway, Chicago 47, Illinois.

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CIRCLE 189 ON READER SERVICE CARD

NEW!

Automatically Operated
Remotely Controlled
PNEUMATIC PRESSURE REGULATOR

SAFE! Unprecedented in response and sensitivity. Not only does Marotta's new RV-23E Regulator Series load and vent pressure with push-button efficiency over a wider pressure range than any existing regulator or series of regulators, but is the only regulator meeting automation demands ...the RV-23E can be programed to operate systems at a different pre-determined pressure level sequence.

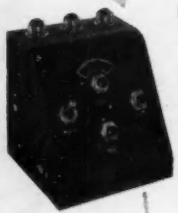
SPECIFICATIONS:

Model:
Regulator—¼" dome loaded pneumatic pressure reducer
Remote Control type 24 V. D. C. Solenoid operated

Pressure Characteristics:
Inlet, outlet, and gage ports per MS 33656-4
Inlet pressure range—30 p.s.i.g. to 6000 p.s.i.g.
Proof pressure—9000 p.s.i.g.
Burst pressure—15,000 p.s.i.g.

Outlet pressure range—30 p.s.i.g. to 5000 p.s.i.g.
Proof pressure—7500 p.s.i.g.
Burst pressure—12,000 p.s.i.g.

Rated Capacity 0.1 (SCFM/PSIA) min.
(as defined in MIL-R 8572A)



PRV-11A Special 6", 160 psi LOX Pressure relief

MV-74-H ⅜" three-way 6000 psi General Purpose Solenoid

MV-41A ⅜" N.C. 1000 psi Fuel Solenoid

RV-4C ⅜" 60 psi Integral Relief Pressure Regulator

MV-36S ⅛" N.C. 3500 psi Internally Piloted Solenoid

Write or call for complete information.
Experienced engineers available for consultation.

Marotta VALVE CORPORATION

pioneer producers of high pressure valves

P.O. BOX 330-J BOONTON, N. J.

NEW PRODUCTS

Long term stability is 100 ppm. Both a portable bench model and a 19-in. rack mount model sell for $795.–Kintel Div. of Cohu Electronics, Inc., San Diego, Calif.

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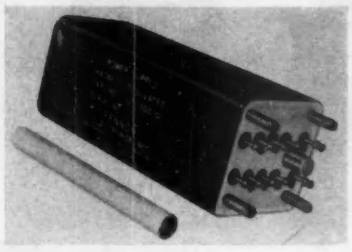

TELEMETERING SUPPLY

Weighing just 20 oz, this hermetically sealed miniature magnetic power supply eliminates the effects of line transients and exhibits a high power conversion efficiency.

Characteristics:
Output: 100 ma at 150v
Input: 115 volts, 400 cycle
Regulation: within 0.25 percent for 10 percent line and load variations
Dimensions: 1¾ x 1¾ x 4 in.
–Pennon Electronics, Inc., Bell Gardens, Calif.

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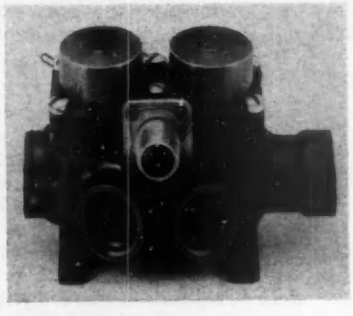
ACTUATORS & FINAL CONTROL ELEMENTS



SELECTOR VALVE

This new 4-way, 3-position solenoid-operated selector valve, designed for 3,000-psi service, uses a forged stainless steel body with an integral sleeve. This design eliminates more than one-half the number of packings usually required. Each position of the valve is

CAREER OPPORTUNITIES AT TI

DEVICE DEVELOPMENT ENGINEER

26,000 TI transistors will be produced from the thin slices of germanium crystal seen in the container above being inserted into a diffusion furnace. In circle at left, precisely separated on single slice (magnified 10 times) are 37 of more than 1,000 transistor hearts per slice.

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1141 E. Jersey St.
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INCORPORATED
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a vital supplement to Sorensen's complete line of voltage regulating transformers

Three models of Sorensen voltage-regulated plate and filament transformers now provide a low-cost, compact way to protect critical industrial electronic, audio, video and instrumentation circuits against "line bounce" and poor line voltage regulation.

Sorensen MVRP's easily replace most ordinary plate and filament transformers. They increase circuit reliability, extend component life by regulating 6.3 vac and 5.0 vac filament voltages as well as plate voltage. Write for complete data. Sorensen & Company, Richards Ave., South Norwalk, Connecticut.

ELECTRICAL SPECIFICATIONS

Input, all models: 100-130 vac, 60 cps, single-phase.
Regulation: All windings regulated ±3.0% unless otherwise specified.
Output voltage tolerance: ±7.0% all windings.

Model Number	D-c Input to Filter* From Regulated Center-Tapped H-v Winding	Regulated Filament Windings	
		6.3 vac	5.0 vac
MVRP-40	275 vdc at 50 ma.	2.5 amps, ct	2.0 amps
MVRP-70	385 vdc at 110 ma.	3.0 amps, ct	2.0 amps
MVRP-185	380 vdc at 250 ma.	Two windings: 4.0 amps plus 8.0 amps unregulated	3.0 amps

*Nominal value taken at output of type 5Y3GT rectifier for Models MVRP-40 and MVRP-70 and type 5U4GA/GB for MVRP-185. Regulated 5.0-volt filament winding for the rectifier tube must be used for ±3.0% guaranteed regulation of plate voltage output.

Separate capacitor furnished with each transformer.
CUSTOM UNITS FOR SPECIAL REQUIREMENTS CAN BE SUPPLIED. 9.60

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192 CIRCLE 192 ON READER SERVICE CARD

pressure-actuated; springs serve only as safety devices. Operating temperature is 275 deg F.—Hydra-Power Corp., New Rochelle, N. Y.

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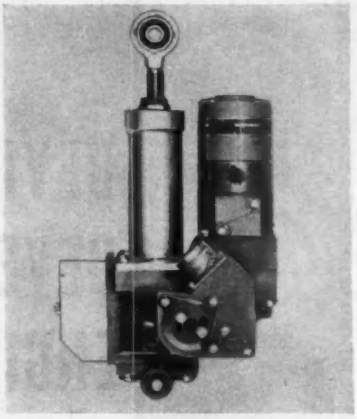

PRECISION ACTUATOR

A precision control device, this new linear actuator provides load capacities of from 100 lbs tension to 600 lbs compression with little change in ram speed. Its ram operates at from 0.3 to 0.6 in. per sec. Ram position signals, accurate to within 0.001 in., are transmitted by a position-indicating potentiometer. Features include mechanically-operated limit switches backed up by nonjamming mechanical stops, and a radio noise filter. Designed for intermittent duty, the actuator operates on 25-29 vdc, draws a maximum of 12 amps, and weighs 3 lbs.—Hydro-Aire Co., Burbank, Calif.

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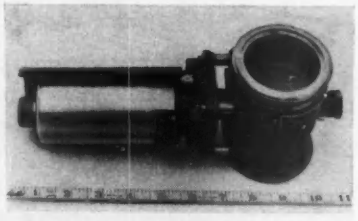

HIGH TEMPERATURE VALVES

Originally designed to permit control of engine bleed air to a boundary layer control system, this new shutoff valve is electrically actuated by a 28-vdc motor. In a closed position it will withstand line pressures up to 255 psid with inlet temperatures up to 910 deg F. Its patented butterfly seal holds internal leakage to less than

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3	13	23	33	43	53	63	73	83	93	103	113	123	133	143	153	163	173	183	193
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9	19	29	39	49	59	69	79	89	99	109	119	129	139	149	159	169	179	189	199
200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390
201	211	221	231	241	251	261	271	281	291	301	311	321	331	341	351	361	371	381	391
202	212	222	232	242	252	262	272	282	292	302	312	322	332	342	352	362	372	382	392
203	213	223	233	243	253	263	273	283	293	303	313	323	333	343	353	363	373	383	393
204	214	224	234	244	254	264	274	284	294	304	314	324	334	344	354	364	374	384	394
205	215	225	235	245	255	265	275	285	295	305	315	325	335	345	355	365	375	385	395
206	216	226	236	246	256	266	276	286	296	306	316	326	336	346	356	366	376	386	396
207	217	227	237	247	257	267	277	287	297	307	317	327	337	347	357	367	377	387	397
208	218	228	238	248	258	268	278	288	298	308	318	328	338	348	358	368	378	388	398
209	219	229	239	249	259	269	279	289	299	309	319	329	339	349	359	369	379	389	399

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7	17	27	37	47	57	67	77	87	97	107	117	127	137	147	157	167	177	187	197
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201	211	221	231	241	251	261	271	281	291	301	311	321	331	341	351	361	371	381	391
202	212	222	232	242	252	262	272	282	292	302	312	322	332	342	352	362	372	382	392
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206	216	226	236	246	256	266	276	286	296	306	316	326	336	346	356	366	376	386	396
207	217	227	237	247	257	267	277	287	297	307	317	327	337	347	357	367	377	387	397
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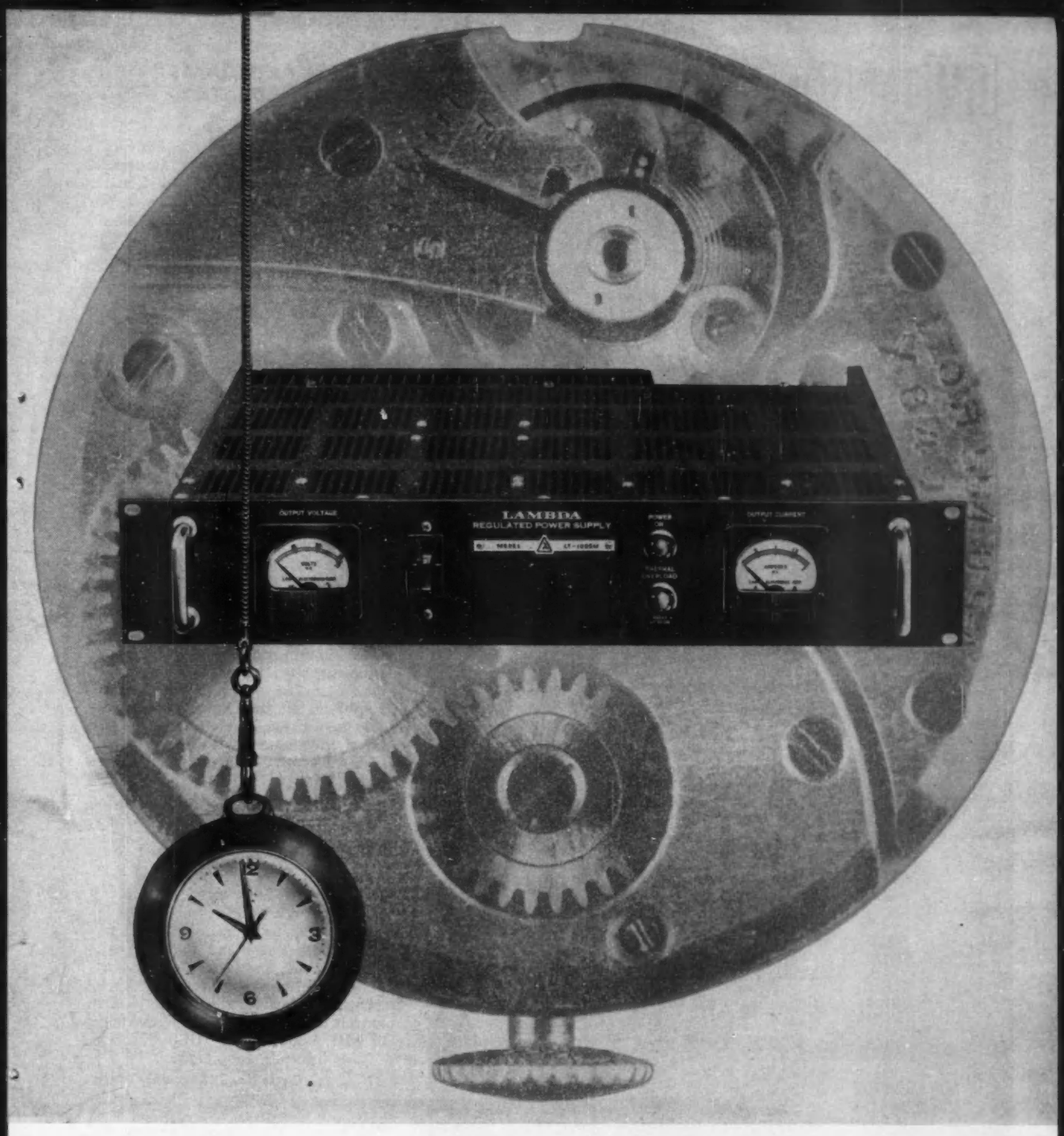

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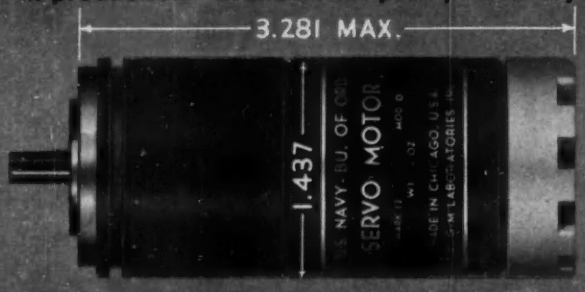
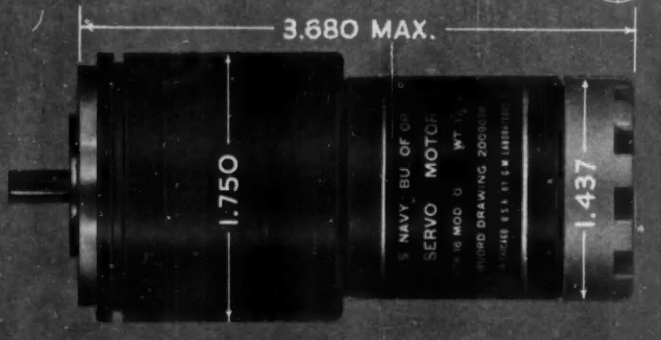
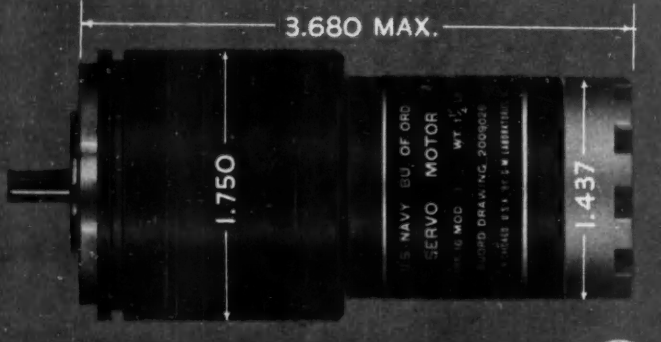


BuOrd Mark 12 Mod 0 SERVO MOTOR Tachometer Generator 115 volts / phase, 4500 RPM (min).



BuOrd Mark 16 Mod 0 SERVO MOTOR Tachometer Generator 115 volts / phase, 4500 RPM (min).



BuOrd Mark 16 Mod 3 SERVO MOTOR Tachometer Generator for transistor operation 115 volts fixed phase 36/18 volts control phase, 4500 RPM (min.)

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NEW PRODUCTS

0.25 ppm against a inlet pressure of 320 psig.—Sierra-Schroeder Controls Div., Idaho Maryland Mines Corp., Glendale, California

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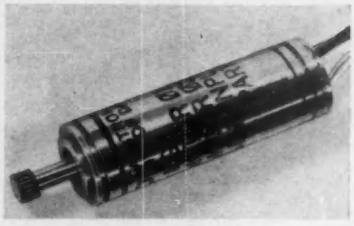


WORLD'S SMALLEST

This brand new Size 5 motor-generator, smallest in its field, weighs less than one-half as much as its Size 8 counterpart yet provides the same working efficiency. The unit develops a stall torque of 0.1 oz-in. and has a no-load speed of 10,000 rpm. Weight, including leads, is just 1.0 oz. Units are available for 400-cycle operation with 26 or 33 control phase windings. In missile applications these units will require smaller power supplies, servo amplifiers, and heat sinks and will be able to withstand more severe vibrational environments.—Daystrom Transicoil, Div. of Daystrom, Inc., Worcester, Pa.

Circle No. 323 on reply card

COMPACT ACTUATORS

Excellent reliability results from design simplicity and rugged construction of a new line of miniaturized electromechanical actuators. Line includes both rotary and linear types. Units feature low backlash, accurate positioning, adjustable limit switches, and nonreversible gear trains. All models comply with the requirements of MIL-A-8064A and MIL-E-5272A. —Nash Controls, Inc., Newark, N. J.

Circle No. 324 on reply card

PLUS . . .

(325) A one-horsepower gearmotor, less than 2½ in. in diameter, has been developed by the **Electro Products Div.** of Western Gear Corp., Pasadena, Calif. . . . (326) **Barksdale Valves**, Los Angeles, Calif., has introduced a new line of momentary contact **air valves** in which coil current is applied only during valve motion.

Circle No. 325 or 326 on reply card

BULLETINS AND CATALOGS

(350) PROCESS CONTROLS. The Swartwout Co. Bulletin A-913, 8 pp. Designed as a guide to the company's line of electronic controls for the process and power industries, this bulletin features an illustrated chart arranged to show the various kinds of equipment available for given process variables. Brief introductory section explains basic operating problems.

(351) MASS FLOWMETER. General Electric Co. Bulletin GEA-6925, 8 pp. Describes theory, operation, and advantages of a new gyro-integrating mass flowmeter designed to handle both liquids and gases. Features include two cutaway drawings illustrating its construction and operation and a table of specifications.

(352) FULL METER LINE. Helipot Div. of Beckman Instruments, Inc. Catalog, 20 pp. Covers three separate product lines: expanded-scale dc and ac voltmeters, expanded-scale frequency meters, and linear-scale ammeters. Each is presented individually and detailed from primer-like operating principles through complete specifications. Photos and drawings illustrate case styles and dimensions.

(353) LOW-LEVEL AMPLIFIER. Epsco, Inc. Data Sheet, 2 pp. Describes the BA-102 wide-band, low-level differential dc amplifier, an instrument designed to handle highly dynamic data from strain gages, load cells, thermocouples, and other low level sources. Illustrations include response curves for various selectable gains.

(354) PRECISION POTS. Guidance Controls Corp. Six data sheets, each 2 pp. Each sheet covers a different type of single turn potentiometer and presents complete electrical and mechanical specifications, a table of special features, a dimension drawing, and curves.

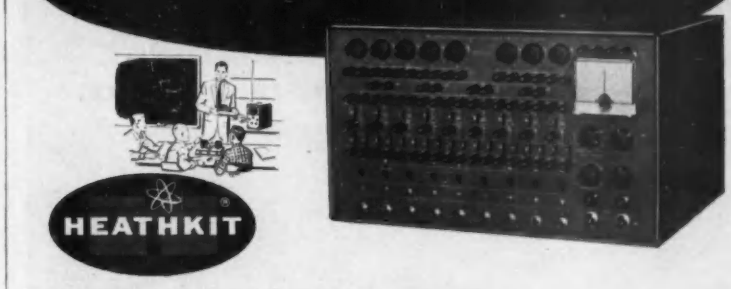
(355) HIGH-VACUUM EQUIPMENT. Rochester Div., Consolidated Electrodynamics Corp. Bulletin 10-1, 28 pp. Supplementing earlier bulletins on vapor pumps, distillation equipment, and gages, this new bulletin covers a variety of valves, baffles, and traps for high-vacuum work. Descriptions of each are accompanied by photographs, line drawings, and tabular dimensional data. Also includes a useful valve selection guide.

(356) HYBRID SYSTEMS. Computer Equipment Corp. Brochure, 10 pp. Describes the company's facilities and capabilities for the research and development of hybrid computer systems. Also provides brief descriptions of several developments that are now being produced in quantity. Included are digital subtractor-converter and microvolt decimal digit converter.

(357) BOILER CONTROLS. Copes-Vulcan Div., Blaw-Knox Co. Bulletin 1057, 12 pp. Explains solutions to some interesting control problems at the Deep Water Station of the Atlantic City Electric Co., where process steam must be furnished to an adjacent chemical plant. Contains a 2-page schematic of the entire Copes-Vulcan system.

(358) INDUSTRIAL AUTOMATION. General Electric Co. Bulletin GEA-6939,

NEW! An Electronic ANALOG COMPUTER KIT for just $199.95



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The lowest priced computer of its quality available anywhere, the new Heathkit EC-1 Computer now puts advanced engineering techniques within reach of all.

Industry will find the EC-1 invaluable in trial solutions to mechanical and mathematical problems . . . shortens engineering time, speeds up preliminary work, frees the advanced-computer time for more complex problems and final solutions. And the EC-1 aids in training computer operators and acquainting engineers with computer versatility and operation.

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Set up scores of complex problems with the assortment of precision components and patch cords supplied. Read problem results directly on the 3-range computer meter, or use an external read-out device such as the Heathkit OR-1 DC Oscilloscope, or a recording galvanometer. Meter can be switched to read output of any amplifier for problem results or balancing purposes. Informative manuals provided show how to set up and solve typical problems, illustrate operating procedures, and supply basic computer information, references, and construction procedure. Shpg. Wt. 43 lbs.

SPECIFICATIONS: Amplifiers: 9 D.C. Operational Amplifiers using one 6U8 per amplifier; each solves mathematical problems; each balanced by individual panel control without removing problem set-up. Computing components mount on connectors and plug into panel sockets. Open loop gain approximately 1000. Output −60 to +60 volts at 3 ma. **Power Supplies:** +300 volts at 25 ma electronically regulated; variable from +250 to +350 by control with meter reference for setting +300 volts. Negative 150 volts at 40 ma regulated by VR tube. **Coefficient Potentiometers:** Five on panel. **Initial Condition Potentiometers:** Three on panel; used to introduce initial velocity, acceleration, etc. on the three "given" quantities. **Repetitive Operation:** Multivibrator cycles a relay at adjustable rates (.1 to 15 CPS), to repeat the solution any number of times; permits observation of effect on solution of changing parameters. **Meter:** 50-0-50 ua movement. **Power Requirements:** 105-125 volts, 50-60 cycles, 100 watts. **Dimensions:** 10¾" W. x 11⅛" H. x 15" D.

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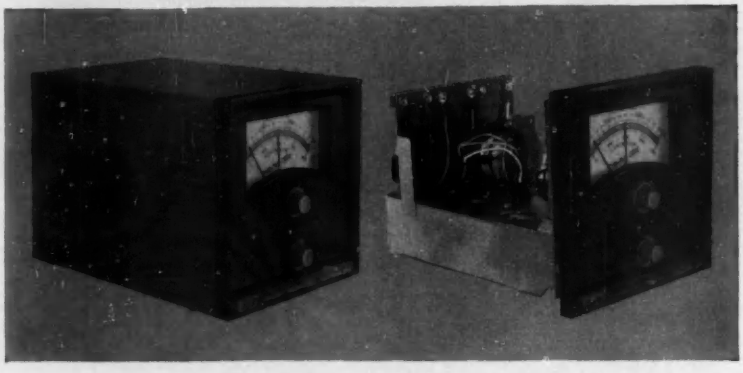
NO TEMPERATURE OVERSHOOT

WHEN SIMPLYTROL MINDS THE POT



TIME-PROPORTIONING CONTROL HAS UNIQUE ANTICIPATING ACTION

The new A.P.I. *Simplytrol* brings an extremely high degree of precision to low-cost temperature control. On most applications, this meter-relay-actuated controller will hold temperature accurately to within ±1°F. of a desired set point.

An ingenious anticipating circuit aids in the "pot minding." When the measured temperature approaches the set point, an electrostatic attraction is created between the contacts on the indicating and adjustable pointer-arms. This electrostatic force increases rapidly as the contacts move closer together and causes premature closing of the circuit, thereby avoiding temperature overshoot by early shut-off.

Built around the well-proven A.P.I. meter-relay design, Simplytrol is a complete controller package which uses no amplifying circuits or vacuum tubes: it is perfectly stable, thoroughly reliable. And it costs much less than comparable temperature controls.

Available in thirty ranges from −400°F. to +3000°F., Simplytrol is packaged in an attractive case that converts in minutes from table-top enclosure to panel-mounting rack. Special models offer an adjustable time-proportioning band.

For complete information, request Data Sheet 9-B.

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Bulletins & Catalogs

28 pp. Entitled "A Guidebook to Automation through Modernization for the Metal Rolling & Processing Industry", this publication explains GE's "Ring of the Future" concept of progressive automation, describes the tools of automation, discusses planning, and provides a detailed breakdown of automation potential in reversing hot mills, hot strip mills, cold mills, processing lines, and specialized processes.

(359) REGULATING TRANSFORMER. Raytheon Co. Bulletin, 4 pp. Offers complete specifications on three new voltage regulating plate-filament transformers for use in electronic power supplies. Illustrations include photographs, dimension drawings, and a schematic showing how one model has been used in a typical full-wave rectifier circuit.

(360) RELAY CATALOG. Universal Relay Corp. 44-pp. Lists and describes a wide variety of relays, stepping switches, solenoids, contactors, and related items from many manufacturers. Most of the items shown are carried in stock in production quantities.

(361) PULSE EQUIPMENT. Electro-Pulse, Inc. 1959-60 general catalog, 48 pp. Offers complete specifications on a variety of pulse generators and electronic counters. Features include notes on pulse generating equipment, counter and totalizer information, and a full page applications index.

(362) AUTOMATIC GAGE CONTROL. General Electric Co. Bulletin GEA-6947, 2 pp. Briefly describes GE's new gagemeter control system which automatically controls mill systems to roll continuously uniform strip.

(363) LEAK DETECTOR. Consolidated Electrodynamics Corp. Bulletin 1830, 4 pp. Applications, specifications, and operation of a portable mass-spectrometer-type leak detector are discussed with the help of a flow diagram, photographs, and descriptions of accessories.

(364) EDUCATIONAL COMPUTER. Computer Controls Co., Inc. Catalog S1, 14 pp. General description of the SPEC, stored program educational computer, is followed by a list of specifications, a block diagram, a typical program, and detailed discussion of its physical components. Includes price and delivery information.

(365) TRIGISTOR APPLICATIONS. Solid State Products, Inc. Bulletin D410-02, 16 pp. Covers some interesting applications of the company's Silicon Trigistor, a circuit-equivalent component with characteristics comparable to the circuit function of a flip-flop. Demonstrates how these components have been used to simplify design and improve reliability.

(366) AUTOMATIC TEST EQUIPMENT, Kearfott Co., Inc. Bulletin, 16 pp. Uses 12 block diagrams to illustrate descriptions of automatic equipment for testing the electronic characteristics of capacitors, fixed and variable resistors, diodes, and transistors.

(367) WATER & SEWAGE PLANTS Minneapolis-Honeywell Regulator Co. Booklet D97-2, 30 pp. A compilation of

article reprints from Honeywell's *Instrumentation* magazine, this booklet offers some field-proven solutions to many of the instrumentation problems peculiar to water and sewage treatment plants. Tells of instruments used and how they provide automatic control of the various treatment processes.

(368) PULSE HEIGHT ANALYZER. The Victoreen Instrument Co. Form 3021-9, 4 pp. Deals with the operation and application of a new 100-channel pulse height analyzer. Includes a complete list of specifications as well as a photo and block diagram of the unit.

(369) SPRING CLUTCHES. Marquette Div. of Curtiss-Wright Corp. Bulletin, 28 pp. Deals with the application, operation, and construction of five standard lines of spring clutches: over-running and back-stopping types, indexing types, on-off types, combination on-off and indexing types, and safety lock control types. Load calculation and dimension data are included to simplify the selection problem.

(370) MILITARY COMPONENTS. Ohmite Mfg. Co. Catalog, 32 pp. Serves not only as a catalog of military electronic components but also as a useful handbook on the various military specifications pertaining to these components. Products include resistors, rheostats, tantalum capacitors, and a variety of relays.

(371) NEW POTTING COMPOUND. Dow Corning Corp. Bulletin 10-505, 4 pp. Graphically describes the properties and applications of Dow's Dielectric Gel, a new silicone potting compound that permits visual and instrument checking of individual parts within a potted assembly. Graph illustrates its negligible stress-temperature character.

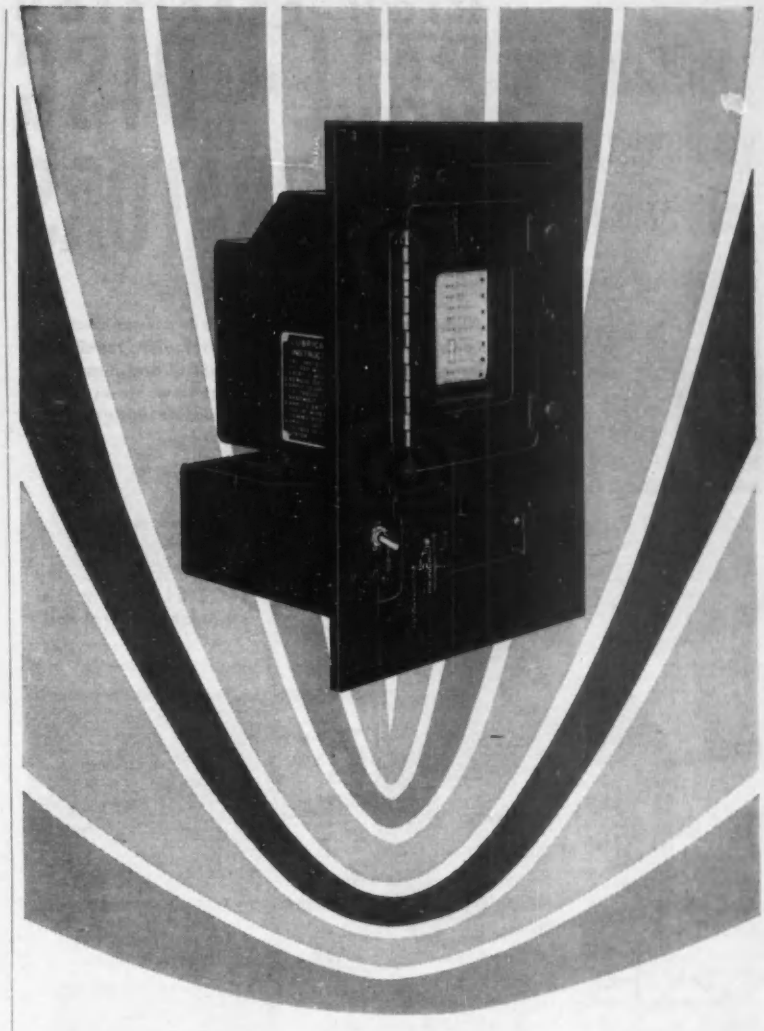
(372) PRECISION ELECTRONICS. Davenport Mfg. Co. Booklet, 12 pp. Contains detailed descriptions and illustrations of precision electronic equipment for research and industrial applications. Included are dc power supplies, digital-readout voltmeters, ac line voltage regulators, and information on the company's custom design and prototype development services.

(373) OPTICAL STRAIN GAGE. American Instruments Co. Bulletin 2294, 8 pp. Offers information on the operation and application of a new optical strain gage system designed to measure strains as low as 2 μin. Features include a useful bibliography and ordering information for both standard and high temperature gages.

(374) LIQUID LEVEL CONTROLLERS. Minneapolis-Honeywell Regulator Co. Specification S1017-1, 4-pp. Photos, schematics, and dimensional drawings illustrate this technical description of an electronic liquid level controller. Single- and double-probe models are described.

(375) BLOWER DATA. Air-Marine Motors, Inc. Catalog, 12 pp. Features 54 flow charts, complete electrical specifications, and physical dimensions covering a variety of single unit centrifugal blowers. Short section on sizing blowers for particular applications serves as a design aid.

(376) SERVOMOTOR CATALOG. John Oster Mfg. Co. Catalog 5000, 20 pp. Lists basic models and characteristics of servomotors from size 8 to size 29. Illustrations include dimension drawings, typical performance curves, and circuit diagrams.



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WITHSTANDS 50G SHOCK!

The new Model 2000 series printers designed by Clary will print digital data even under the extreme environmental conditions encountered in military use • These rugged, reliable printers are constructed on a sturdy panel for vertical rack mounting, and contain all necessary electronic equipment for data decoding, digit selection, and control functions of the printer • They are designed to print the output from computers, digital voltmeters, shaft position transducers, electronic counters and digital clocks. In addition, they are ideal in industrial applications where continuous, unfailing operation is required • For complete information on how Clary Model 2000 series can help you, write today for Engineering Bulletin S-120 •

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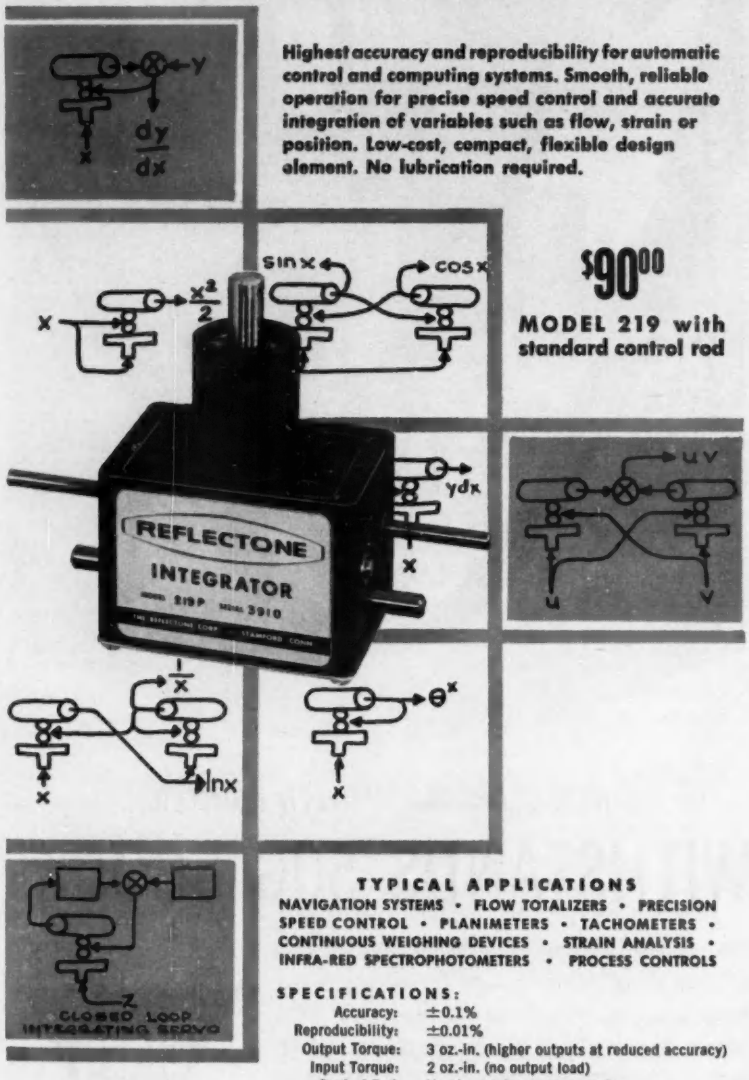

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MODEL 219 with standard control rod

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Reproducibility:	±0.01%
Output Torque:	3 oz.-in. (higher outputs at reduced accuracy)
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Output Speed:	Reversible up to more than twice the input

Additional mechanical specifications and applications data available on request.

REFLECTONE

REFLECTONE ELECTRONICS, INC. • STAMFORD, CONNECTICUT

WHAT'S NEW

(Continued from page 56)

TRW Spawns Intellectronics; Acquires Three Other Firms

Thompson Ramo Wooldridge, Inc., fast-growing many-faceted corporation has been able to keep its hunger for new operating units down to only one per month. The past four months have seen TRW purchase or originate from within four new operations.

Just last month the Ramo-Wooldridge Div. coined a new word, intellectronics, to describe the activities of a new lofty unit formed within the division. Intellectronics Labs. will be devoted to the science of extending the intellect through the use of electronics. Real reason for the formation of the group seems to be a desire to tie together several somewhat autonomous projects now underway at R-W. These include development projects in automatic language translation, combat command systems, industrial process control, air traffic control, and data retrieval. Head of Intellectronics Labs. will be John M. Salzar, Control Personality and CtE author (Sept. '57, pp. 25 and 183).

In July TRW acquired a controlling interest in Magna Products, Inc. of Santa Fe Springs, Calif. Magna produces specialty chemicals and electronic instruments for the west coast oil, gas, and chemical industries.

A month later came the purchase of Bell Canto Stereophonic Recordings, Inc., which markets prerecorded stereo tape and disc recordings. As a TRW subsidiary Bell Canto became a member of the Commercial Electronics Group which already included Bell Sound Div. (hi-fi components and intercommunication and public address systems) and Dage Television Div. (closed-circuit TV).

Latest member of the Commercial Group is Magnetic Recording Industries of New York City, a producer of educational electronic equipment. Their specialty is systems for teaching languages and similar subjects.

Fischer & Porter Acquires Rights to Quarie Maximizer

The Quarie Maximizer, an optimizing process controller, will now be built, sold, and serviced by Fischer & Porter Co., Hatboro, Pa. The Maximizer, which was developed by Quarie Controllers, Canton, Mass., is a simple analog computer for which F&P foresees numerous applications in conductivity control, maximizing effi-

ciencies, difficult stability problems, and maximum power transfers.

B-58 Bomb-Nav System Award To Sperry For $142 Million

Sperry Gyroscope Co., Div. of Sperry Rand Corp., will build inertial bombing-navigation systems and ground support equipment for the Air Force's first wing of 36 B-58 "Hustler" Mach 2 bombers. The $142 million contract includes $38 million for tactical support equipment, indicative of the ground support needed by many complex airborne systems. The support equipment will determine whether the bomb-nav system is functioning properly, show where the faults are, and supply straightforward maintenance instructions.

Convair, Div. of General Dynamics Corp. and weapon system manager for the airplane, will contract with Sperry for the systems for the second SAC wing—if it survives future defense budget cuts, like the one that just felled the entire F-108 program.

New Companies in the Field

Image Instruments, Inc.—to develop electro-optical systems including systems for processing television-type signals, in Newton Lower Falls, Mass. Lester S. Smith, president of the new corporation, was a section head at RCA and chief engineer of Spencer-Kennedy Labs.

Cetec Electronics Co.—to manufacture electronic display equipment, in Palo Alto, Calif. Harrison Johnston, president, was formerly president of Production Research Corp., managing director of Ampex International, and general sales manager of Ampex Corp.

Sandynamics, Inc.—to produce, under license, Markite precision conductive plastic potentiometers, in Ramsey, N. J. Markite Products Corp. was also formed to handle sales and service for the products of both Markite Corp. and the new firm.

IMPORTANT MOVES BY KEY PEOPLE

Johnston Heads ISA; Other Officers Installed

John Johnston, Jr., chief of instrument consultants for du Pont's engineering service division and one of CtE's consulting editors, is the new president of the Instrument Society of America.

He was elected to the top post at the ISA annual conference held in

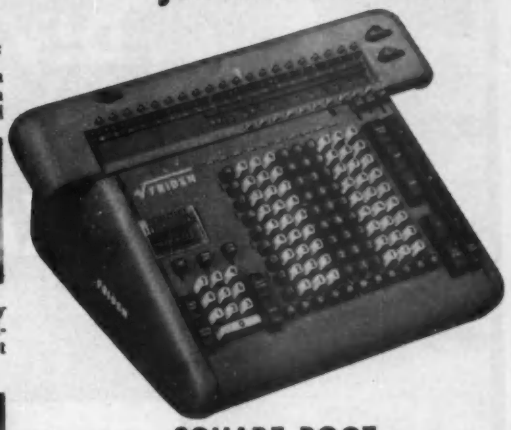
FRIDEN MODEL SRW
—the most extraordinary automatic calculator you have ever seen

STUDY THESE PICTURES:

1 Set number from which root is to be taken on Friden SRW keyboard

2 Touch Square Root key corresponding to position of decimal point in the radicand

3 See root appear in dials. This figure can be retained on keyboard if desired for further calculation. Need for copying root is eliminated



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...appears automatically in the dials of Friden Model SRW when you touch one key

Can you use Friden Model SRW to speed answers? For the first time on any desk calculator it offers touch-one-key extraction of square root. Is equipped also with all automatic Friden Calculator features and so performs more steps in figure-work without operator decisions than any other calculating machine. *The Thinking Machine of American Business* —yours in Friden Model SRW.

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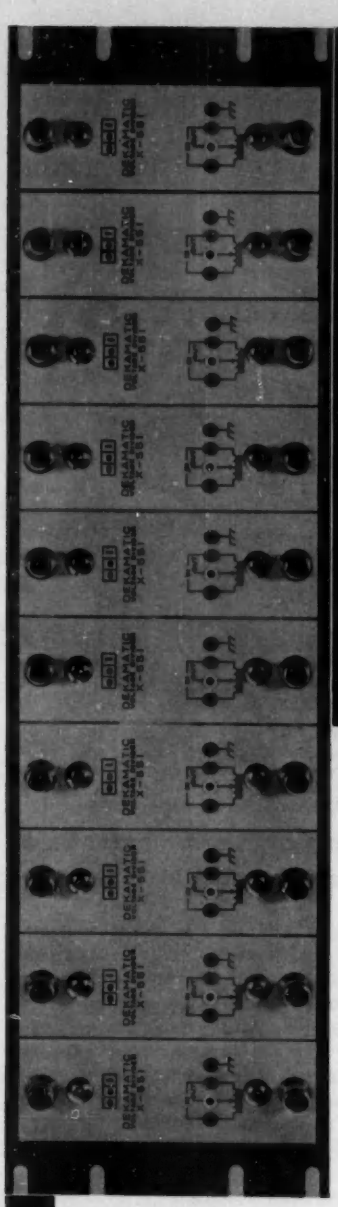

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WHAT'S NEW

Chicago in September (see p. 22). Johnston, who has served ISA as president-elect-secretary for the past year, assumed his new post November 1. He succeeds Henry C. Frost, manager of administrative services for the Corn Products Co.

The new society head joined du Pont in 1946 after spending several years in instrumentation engineering with Standard Oil of N. J. and Sun Oil Co. He reached his present position in 1950. Johnston helped inaugurate the Philadelphia Society for Instrumentation and was a representative at the early meeting that resulted in the formation of ISA. He has represented ISA on the American Automatic Control Council, the U. S. representative to the International Federation for Automatic Control.

Other officers elected at the conference were: president-elect-secretary, Ralph Tripp, Grumman Aircraft Engineering Corp; vice-president, Adelbert Carpenter, Fischer & Porter Co; treasurer, John C. Koch, Conoflow Corp; and regional vice-presidents, Nathan Cohn, Leeds & Northrup Co.; Nelson Gildersleeve, Royal McBee Corp.; John R. Mahoney, Union Carbide Nuclear; Robert C. Mann, General Electric Co.; Milton M. McMillen, Thompson Ramo Wooldridge, Inc.; and Thomas H. Pierson, Eggelhof Engineers, Inc.

Dr. Skinner to Aid Rheem On Teaching Machines

Harvard psychology professor, Dr. B. F. Skinner, pioneer in the field of teaching machines, has assigned his patents to Rheem Manufacturing Co. and will serve the firm as a consultant in its teaching machine program.

The company's Electronics Div. at South Gate, Calif., is conducting research and development in the field and has already demonstrated several models of teaching machines at the American Psychological Convention held in September.

Bush Heads New Setup At Hamilton Standard

The newly organized Electronics Dept. at Hamilton Standard Div. of United Aircraft Corp. will be headed by Walter R. Bush, former vice-president-engineering of Fenwal, Inc. The department is now set up on an autonomous basis, reporting directly to the division's general manager. The unit develops and manufactures electronic

control units for HSD's products—for aircraft propellers, engine controls, and air conditioning systems—and also makes helicopter flight controls, rotor governors, printed circuits, and small electronic components. The new department's charter allows it to seek business in any field, including from industrial customers; all HSD products up to now have been sold for aircraft or to the military. Fenwal makes industrial temperature controls.

Weston Chief Engineer Heads AIEE Instrumentation Div.

The chief engineer of the Weston Instruments Div. of Daystrom, Inc., Dr. Robert C. Langford, has been elected chairman of the newly formed Instrumentation Division of the American Institute of Electrical Engineers. The former AIEE Instrumentation Committee has been upgraded to a full division by the directors, and it will be Dr. Langford's responsibility to fully integrate the group.

Other Important Moves

Evan G. Lapham, formerly with the National Bureau of Standards, has joined Avco Research and Advanced Development Div., Wilmington, Mass., and will take over direction of the Reference Standards Labs. concerned with electrical, radio frequency, and physical measurements.

Ernest Schubert will be technical director of Monitor Systems, Inc., the new Epsco, Inc. subsidiary in Fort Washington, Pa. The firm will engage in the development of automatic checkout and monitoring systems.

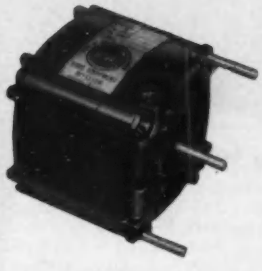
Frank P. Kelly has been appointed manager of manufacturing operations for Minneapolis-Honeywell Regulator Co.'s Brown Instruments Div.

John Buhr of Calgary, Alberta, Canada, is the manager of new Educational Dept. of the National Machine Accountants Association. The group has been set up by the organization to coordinate a long-range program of professional certification, formal education, and training services.

Obituary

William H. Pugsley, vice-president, The Hays Corp., Michigan City, Ind., of cancer. A memorial fund has been set up as a tribute to Pugsley and Shirl M. Rudolph, another Hays vice-president who died of cancer in December 1957. Hays will match employee contributions to the fund which will be used to combat cancer.

. . . electrocardiograph equipment—another Borg Motor application.



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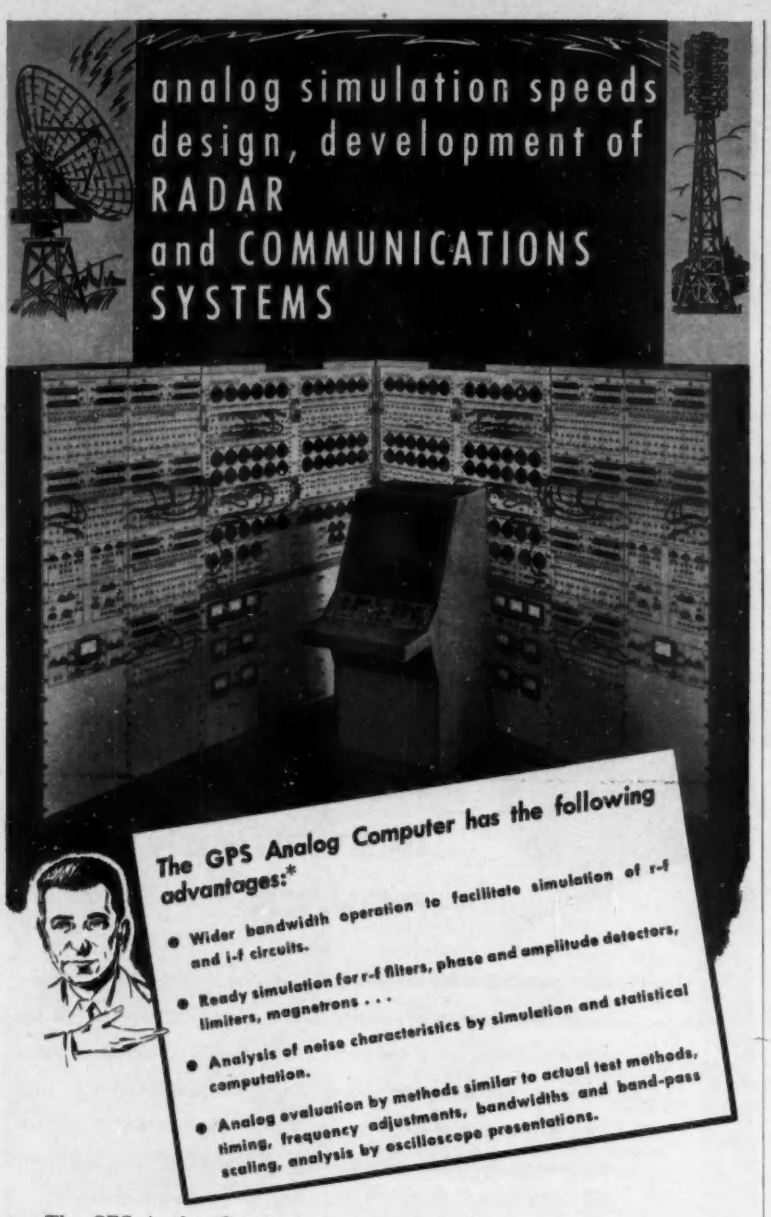
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The GPS Analog Computer is a compressed-time-scale computer operating with an integrator sensitivity of 3000 volts per second per volt. Because of its wide band width operation, the frequency range of simulation of the GPS Computer is several orders wider than that of conventional slow-speed computers.

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ABSTRACTS

Chemist's viewpoint of computing control

From "Statistics in the Chemical Process Industries: Present and Future" by Herbert Grohskoph, American Cyanamid Co. Paper presented at a panel on statistics at the National Meeting of the American Chemical Society, Atlantic City, September 1959.

Every day that passes without definition of the problems in developing a more effective chemical engineering technology brings waste of one sort or another. Nowhere is this more apparent than in the fumbling and the pressures of keeping up with the Jones's that are confusing the processing industries' first experiences with automatic process control. Automatic computer control is a development which logically lies beyond better process understanding, and beyond better methods for chemical reactor design. In this brush with another rapidly advancing technology, the chemical and petroleum industries' need for quantitative process understanding becomes painfully apparent.

Meanwhile elaborate computer control systems are being designed to operate and control processes by naive criteria of process performance:

- Best performance curves, fit visually from scatter charts of existing plant data, have been used as process models for computer control.
- Processes are controlled on the wrong variables, making manual intervention necessary.
- Much systems work is done in a way that offers little assurance that two of the controlled variables may not be fighting each other.
- Too many constants are estimated from too few measurements, taken at too few points.

If this appears to be a diversion from the subject of this paper, I hasten to say that these problems will provide the major subjects for statistical research and development in the years ahead. Even simple statistical methods can help a great deal in solving the control problems listed above. Beyond this, researchers are needed in the design of experiments for chemical rate studies, in making confidence statements about estimated rate constants, in studying process dynamics, estimating transfer functions, working out methods for studying the dynamics of processes with several inputs and several outputs, all of which may, or may

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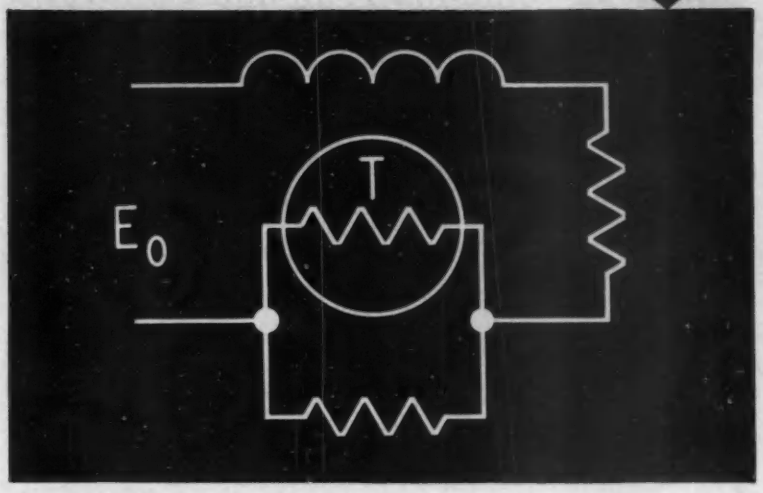

How to enforce the speed limit in tachometer control systems

Temperature changes can seriously affect tachometer output in aircraft and guided missile servo control systems. For example, errors in excess of 2% over an extended temperature range are not uncommon on uncompensated tachometers.

Manufacturers have discovered recently that they are able, with the aid of Glennite Thermistors, to reduce this error to within .4% over a range of −50 to +105°C.

A simple thermistor-resistor network makes this possible. A thermistor is a temperature sensitive resistor with a high negative coefficient of resistance. When properly shunted, its *negative* coefficient compensates for the coefficient of the tachometer—usually about .05% per °C.

Inserted in series with the tachometer output, this network effectively combats temperature changes; provides a relatively constant tachometer output over the full temperature range.

Tachometer compensation is only one of many interesting applications for Glennite Thermistors. Other uses include time delay, temperature control, liquid measurement, fire control, etc.

Glennite wafer, bead and rod thermistors are available in a variety of resistance values, temperature coefficients and sizes to help you evaluate circuit problems. They may be obtained from your local distributor, or from Gulton Industries in bulk quantities.

Test Your Ideas With A Glennite Experimenter's Thermistor Kit

An inquiry on your company letterhead will make available to you a Glennite Experimenter's Kit for $14.95. For those engineers who have had some experience with thermistors, comprehensive kits are available for $49.95. For complete information, write directly to Gulton Industries, Inc.

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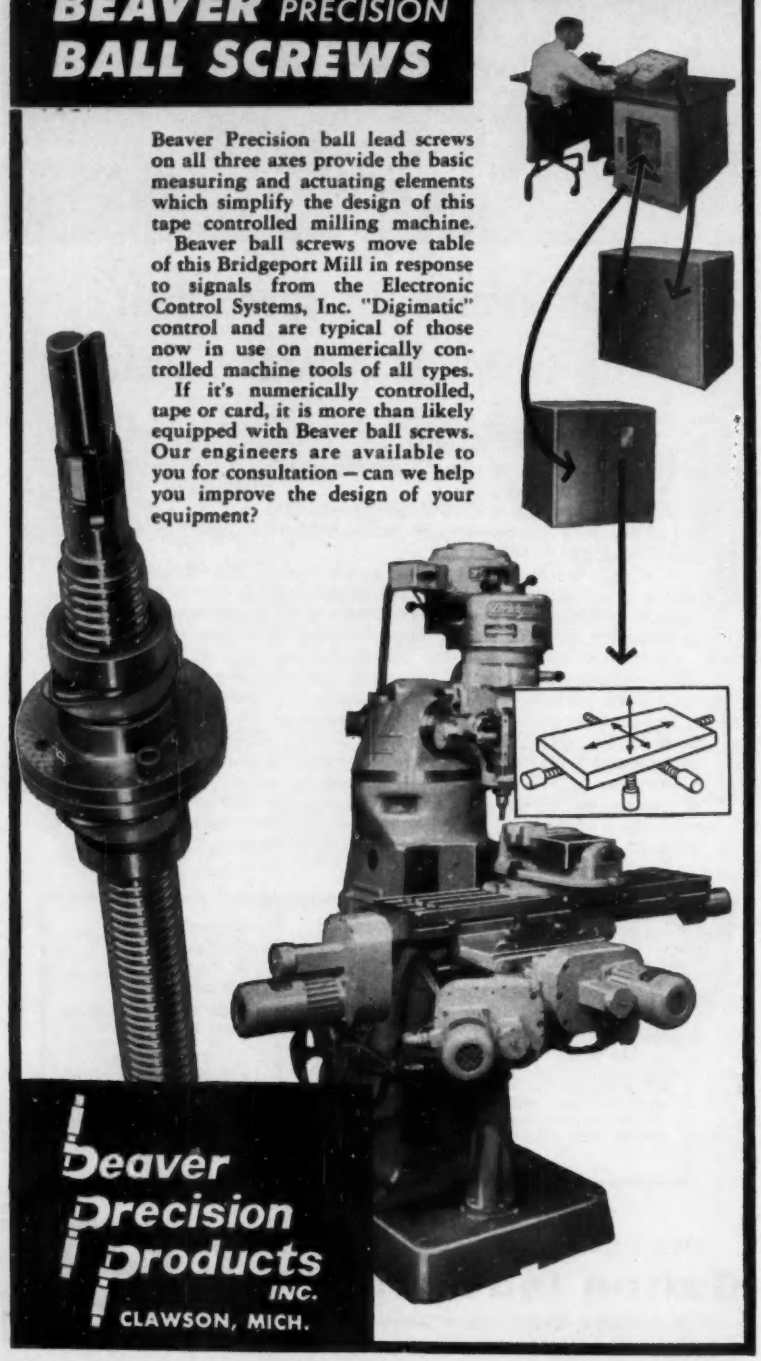
Beaver ball screws move table of this Bridgeport Mill in response to signals from the Electronic Control Systems, Inc. "Digimatic" control and are typical of those now in use on numerically controlled machine tools of all types.

If it's numerically controlled, tape or card, it is more than likely equipped with Beaver ball screws. Our engineers are available to you for consultation — can we help you improve the design of your equipment?



Beaver Precision Products INC.
CLAWSON, MICH.

ABSTRACTS

not be correlated with each other.

These are major objectives, and many years of statistical research will be needed to make work on these problems more tractable.

Effects of Thrust Reversers

From "Flight Measurements of the Effect of a Controllable Thrust Reverser on the Flight Characteristics of a Single-Engine Jet Airplane" by Seth B. Anderson, George E. Cooper, and Alan E. Faye, Jr. NASA Memorandum 4-26-59A, 1959. National Aeronautics and Space Administration.

A flight investigation was made to determine the effect of a continuously controllable thrust reverser on landing approach characteristics. Use of the reverser resulted in improved control of flight-path angle, reductions in approach speed for steep approach angles, and improved wave-off characteristics. A nose-down longitudinal trim change was present with increasing reverser deflection.

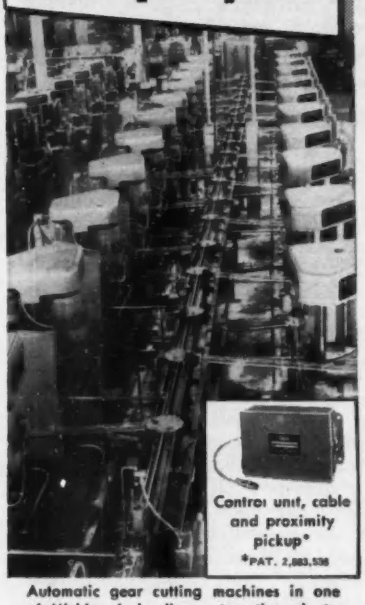
Data recorders reviewed

From "Recorder Survey: Recording Surfaces and Marketing Methods" by George Keinath. National Bureau of Standards Circular 601 issued September 1, 1959. $0.30, 41 pp.

This Circular surveys the characteristics and comparative advantages of continuous traces, dotted traces, and printed characters, as produced by inking, incision, impression, indentation, deposition, heat, light, electric discharge, electron beam, magnetism, chemical action, or fluid streamlines. Descriptive and reference material is included on three physical components of the recording system—the reservoir of material or energy, the marking point or matrix positioned by the measuring element, and the surface which preserves the record.

Preparation of this survey on recording methods and devices was undertaken to bring together available information on the various methods and problems of recording scientific and technical data. The survey covers some of the physical principles either currently or potentially available for recording variable measurands in laboratory experimentation or industrial production. Not included are techniques using coded perforation of tape or cards, or those for conventional magnetic or optical recording of speech, music, or other phenomena with con-

EPL proximity transducer system* ups gear production 1,552,400 units per year!



Automatic gear cutting machines in one of Michigan's leading automotive plants.

400% increase over manual feed!

Automatic gear production line in this plant is monitored by 300 proximity transducers that make stock blank feeding completely automatic. When this system was started in 1957, production figures jumped considerably.

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Rugged Construction—A-C full-bodied design affords full protection; there is no chance of cracking around bolt holes. Vanes are pinned to stainless or monel shafts with high-tensile pins. Oversized outboard roller bearings and retaining plates are used. Rugged standard mounting brackets provide maximum support for any operator in any position.

Flexibility—Valves can be provided in a wide variety of alloys to handle all types of fluids and semi-solids over a wide temperature and pressure range. They may be equipped with almost any operator, which may be mounted in several positions on standard A-C bracket assemblies.

Through Rubber Seats—Full rubber seats on A-C Wafer Valves afford maximum body protection and positive, bubble-tight shutoff. Standard seats are of natural gum rubber, neoprene or hycar. Other materials are available on request.

Size Range—Full-bodied A-C Wafer Valves are available in standard sizes from 3 to 36 inches in both 125# and 150# A.S.A. series, rated as shutoff pressure of 50# and 125#.

For information on the complete line of Rotovalves, and butterfly, ball and wafer valves, contact your nearest A-C valve representative, or write Allis-Chalmers, Hydraulic Division, York, Penna.

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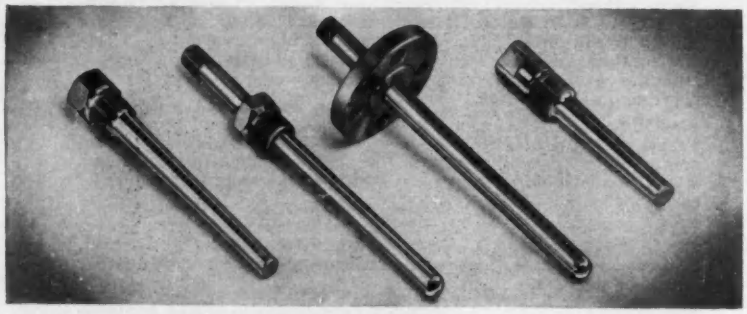

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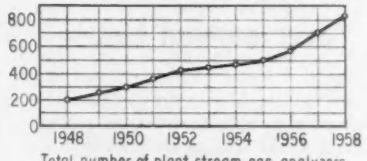
ABSTRACTS

tinual millisecond or microsecond variation. This first volume deals with marking methods and recording surfaces. It is expected that work under way in the reviewing of recorder actuating mechanisms, special recording problems, and data presentation may result in the issuance of a later report.

Burgeoning stream analyzers

From "Dynamic Behavior of Instruments for Gas Analysis in Connection with Automatic Control" by E. Lehrer, Badische Anilin- & Soda- Fabrik AG. Paper presented at the 14th annual instrumentation-automation conference of the Instrument Society of America, Chicago, Ill., Sept. 21-25, 1959.

The application of instruments for continuous analysis of process streams in the chemical industry has made considerable progress within the last decades. This applies particularly to the analysis of gas streams. The figure shows the total number of plant stream gas analyzers in the Ludwigshafen on Rhine plant of the Badische Anilin- & Soda- Fabrik AG for the period 1948 to 1958 and indicates the rapid development in this field.



Total number of plant stream gas analyzers at BASF, Ludwigshafen a.Rh.

The total number has quadrupled in ten years. The reason for this development is the desire to improve process control and quality of products and also to increase safety by early detection of hazardous gas mixtures. The breakdown for 1958 is in the table.

INSTRUMENT	NUMBER
Infrared gas analyzer	290
Photometric instrument	5
Thermal-conductivity gas analyzer	98
Paramagnetic-thermal oxygen analyzer	72
Gas analyzer based on heat of gas-liquid reaction	80
Electrolytic conductance meter	77
Electrochemical oxygen analyzer	29
Continuous rest gas analyzer	19
Catalytic combustion gas analyzer	20
Gas density recorder	90
Heat of combustion recorder	19
Automatic Orsat instrument	28
Plant gas chromatograph	3
	830

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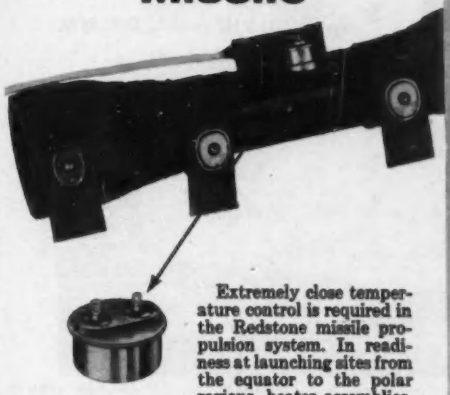
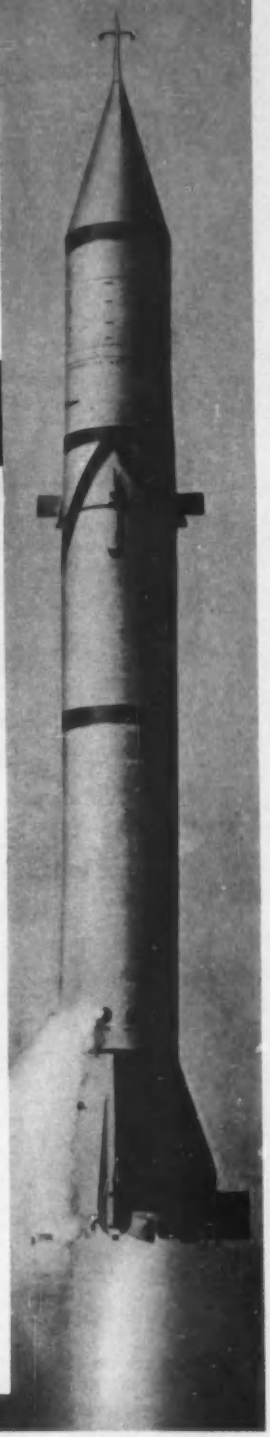
KLIXON Thermostats Provide Rigid Temperature Control for Army's Redstone Missile



ACTUAL SIZE



Extremely close temperature control is required in the Redstone missile propulsion system. In readiness at launching sites from the equator to the polar regions, heater assemblies, developed by Safeway Heat Elements, Inc., Middletown, Connecticut, are mounted directly on or around components in the propulsion system. These heaters withstand temperature extremes from −80°F. to +450°F., and incorporate a unique "snap-on" mounting feature for ease of installation.

KLIXON M1 hermetically sealed thermostats, integrally molded in the heater assemblies, insure the rigid temperature control required. These tiny thermal switches, coupled with an unusually narrow temperature differential and setting tolerance, utilize a saddle type thermal inertia plate for accurately sensing the components.

KLIXON snap-acting thermostats are ideal for such applications for several important reasons — inert gas filled and heliarc welded construction provides a superior seal. Elimination of solder flux and completely inorganic components prevent contact contamination . . . small in size, light in weight . . . responds to temperature change quickly and accurately . . . have ample capacity to handle heavy electrical loads . . . calibrations stand up under severe environmental conditions. Rated: 7 amp, 30 VDC; resistive, 500 cycles. Exceed 50 — 500 CPS, procedure I, MIL-E-5272A.

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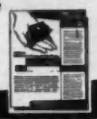

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Stream Analyzers

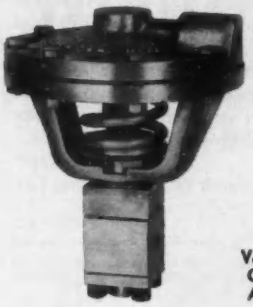
CONTINUOUS ANALYSIS OF CHEMICAL PROCESS SYSTEMS. *Sidney Siggia, Olin Mathieson Chemical Corp. 386 pp. Published by John Wiley & Sons, Inc., New York. $8.50.*

This timely book represents the first serious effort to document the rapidly growing field of continuous stream analyzers. It is definitely recommended reading for all those working on such projects although, like most pioneering literature, it falls short of perfection. In his preface the author sets forth the limitations of the book, the principal one being the uncritical nature of his compilations. The reader may well wish for some evaluation of the several instruments suggested for most applications. However, it is doubtful whether any one author could possibly make such comparisons in view of the newness of the field, the number of process analyzers available, and the variety of applications.

The book presents in extremely compact form much hard-to-find information; it should permit each owner to dump at least one file drawer full of manufacturers' brochures. The coverage is excellent, nearly every major U. S. and many European instruments of importance being covered; however there are a few gaps. *Chemical and Engineering News* (page 82, July 13, 1959) lists fourteen other suppliers of equipment which Siggia does not mention; most of these are either new in this field or otherwise of lesser importance than those quoted. Indexing is excellent, and freedom from typographical errors satisfactory. The topics covered exhaustively include: the physical, optical and electrical tests which reveal chemical composition (ten chapters); direct chemical tests (eight chapters); and X-Ray Fluorescence, Mass Spectrometry, and Sonic Velocity (one chapter each).

Because he has depended largely on manufacturers' sales publications, the author naturally presents a favorable view of each device and says little about its limitations and weaknesses. There is an overabundance of piping details, a shortage of theory, and general unevenness of style and coverage. Operating principles are often given, but there is usually not enough background information to permit an engineer to understand details that may be obvious to an analytical chemist. It would be helpful also to spell out the techniques of successful continuous

MINIATURE VALVES



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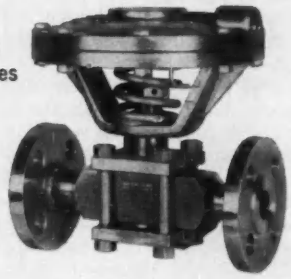

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Seat Area	0.038 sq. in.	up to 0.601 sq. in.
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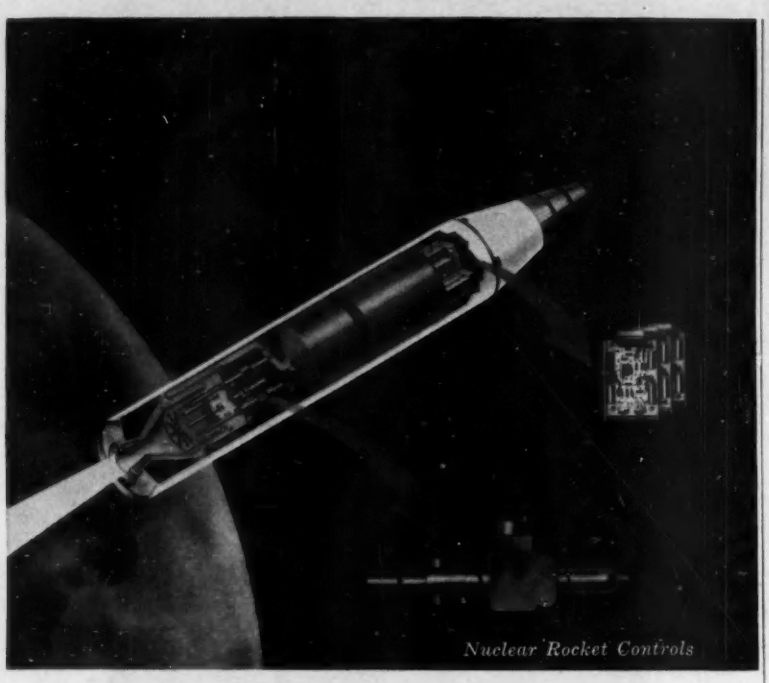
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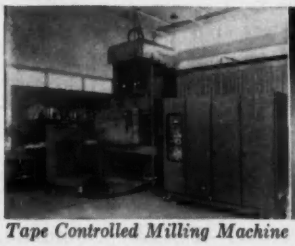
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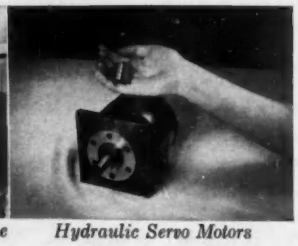
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sampling, which are too often entrusted to the imagination of the local pipefitter. Finally, the very short section on instruments under development deserves expansion; some nuclear methods that are barely mentioned are essentially ready for general use.

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Advanced Fundamentals

INTRODUCTION TO ELECTRONIC ANALOG COMPUTERS, *by John N. Warfield, University of Kansas. 175 pp. Published by Prentice-Hall, Inc., New York. $6.*

This is an excellent advanced text on electronic analog computation. It is aimed at those well versed in electronic analog computers, network analysis, complex variables, and Laplace operational calculus and who wish to increase their understanding of the mathematical foundations of the more elaborate circuits used in electronic analog computers. The book is written almost entirely from a mathematical standpoint and will probably retain its usefulness despite many changes in electronic analog computing techniques. The author makes excellent use of examples so that the book is suitable for home study by someone with a mathematical background. Besides the expected topics of setting up computer simulations, scaling, function generation and checking results, there is also included information on signal graphs, difference equations, and systems engineering.

IRA RITOW
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Fourth Revision

TRANSISTOR MANUAL, *by E. Gottlieb et al. 277 pp. Published by General Electric Co., Semiconductor Products Dept., Charles Bldg., Liverpool, New York. $1.*

A new edition, the fourth, of this manual, contains 277-pages of completely rewritten information on transistors and their use in electronic circuits. Included in the 20 chapters is information on basic semiconductor theory, transistor construction techniques, biasing, switching characteristics, transistor radio servicing techniques and several chapters on circuits. In addition, the book contains a revised and up-to-date listing of all American JEDEC-registered transistor types with their basic specifications and interchangeability information.

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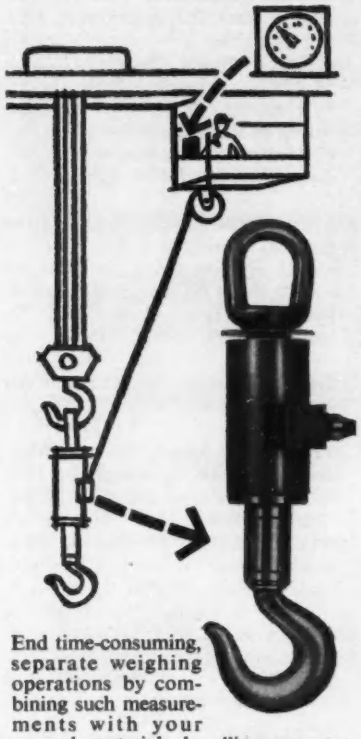

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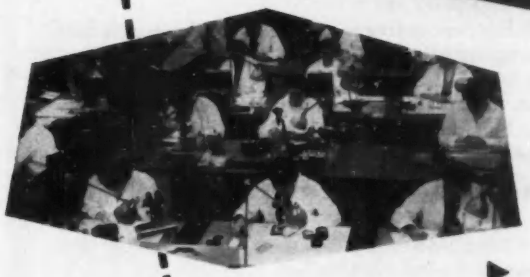

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MEETINGS

NOVEMBER

American Society for Metals, 41st National Exposition and Congress, International Amphitheatre, Chicago, Ill. Nov. 2-6

11th Annual Mid-American Electronics Conference, Hotel Muehlebach, Municipal Auditorium, Kansas City, Mo. Nov. 3-5

American Nuclear Society, Winter Meeting, Sheraton Park Hotel, Washington, D. C. Nov. 4-6

Institute of Radio Engineers, National Conference on Automatic Control, New Sheraton Hotel, Dallas, Tex. Nov. 4-6

Eighth Annual Instrumentation Conference, Louisiana Polytechnic Institute, Ruston, La. Nov. 5-6

Institute of Radio Engineers, Fourth Instrumentation Conference, Atlanta Biltmore Hotel, Atlanta, Ga. Nov. 9-11

National Electrical Manufacturers Association, Annual Meeting, Atlantic City, N. J. Nov. 9-12

Conference on Magnetism and Magnetic Materials, sponsored by IRE and AIEE, Sheraton-Cadillac Hotel, Detroit, Mich. Nov. 16-19

American Society of Mechanical Engineers, Annual Meeting, Chalfonte-Haddon Hall, Atlantic City, N. J. Nov. 29-Dec. 4

27th Exposition of Chemical Industries, New York Coliseum, New York City Nov. 30-Dec. 4

DECEMBER

Fourth Midwest Symposium on Circuit Theory, sponsored by IRE Professional Group on Circuit Theory, Brooks Memorial Union, Marquette University, Milwaukee, Wisc. Dec. 1-2

Eastern Joint Computer Conference, Sponsored by AIEE, ACM, and IRE, Hotel Statler, Boston, Mass. Dec. 1-3

American Institute of Chemical Engineers, Annual Meeting, Sheraton Palace Hotel, San Francisco, Calif. Dec. 6-10

JANUARY

Sixth National Symposium on Reliability and Quality Control, sponsored by IRE, AIEE, ASQC, and EIA, Statler Hilton Hotel, Washington, D. C. Jan. 11-13

American Institute of Electrical Engineers, Winter General Meeting, New York City Jan. 31-Feb 5.

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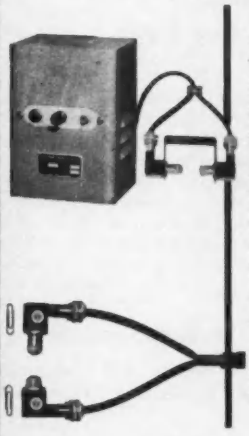

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WHAT'S AVAILABLE IN REPRINTS

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Some reprints are individual articles, while others are "packages"—several articles published over a period of time that logically supplement one another in the coverage of a specific phase of the control field. Any reprint can be obtained at the nominal cost listed below by filling in the order form and sending it, together with remittance, to Readers Service Dept. Quantity rates will be quoted on request.

How to Use the Root Locus in Control System Design, 12 pp. Another reprint that translates theory into practice. Eight simple rules make locus construction easy, even including the effects of distance-velocity lags. Articles show how to interpret the locus diagram, how to determine transient response, and how to use locus techniques with multi-loop systems. **45 cents.**

Complete Analysis Instrumentation Series, 112 pp. Special rate for those who order all three parts (I, II, and III) of Analysis Instrumentation Series; 17 percent discount on 112 pages of timely technical information for process control engineers. $1.75.

Analysis Instrumentation—III—Electrochemical Methods, Mass Spectrometry, Continuous Viscometers, X-Ray Techniques, K-Capture, Physical and Chemical Property Testers, Emission Spectroscopy, 112 pp. Reprint includes last nine articles of Analysis Instrumentation Series. $.90.

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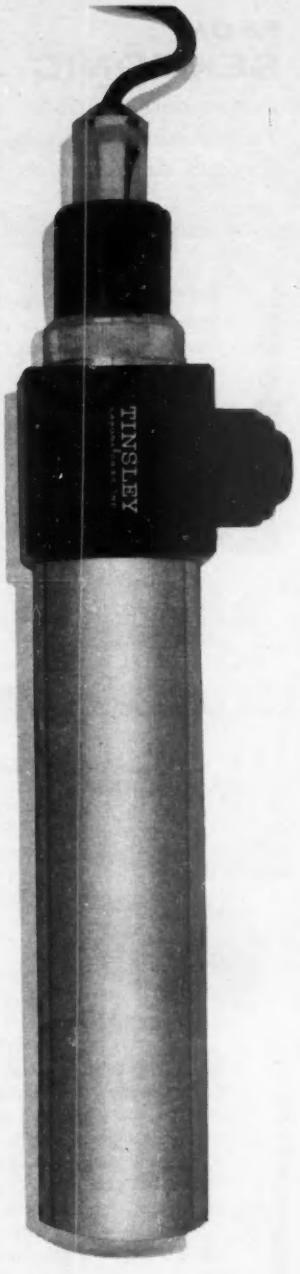

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Analysis Instrumentation — I — Nuclear Magnetic Resonance, Chromatography, Radioactivity, 32 pp. Reprint consists of first 4 articles of Analysis Instrumentation Series: a general introduction and detailed discussions of the three analysis techniques. Emphasis is on basic principles, practical tips, and the use of these techniques in automatic process control. 60 cents.

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A Roundup of Control System Test Equipment, 24 pp. Specialized control system test equipment divides into three classes: 1) devices that only generate a test signal, 2) systems that both disturb the system and provide a means for evaluating response, and 3) devices that only evaluate control system response. A survey of equipment and tips on using it. 60 cents.

Survey of Ac Adjustable-Speed Drive Systems, June 1959, 16 pp. Largely regarded as constant-speed devices, multispeed ac actuators actually take many efficient forms. The recent resurgence of interest in these ac adjustable-speed systems prompted this comprehensive coverage of pole-changing techniques, armature resistance control of wound-rotor motors, frequency changing, slip-frequency injection, and the use of eddy-current couplings. 50 cents.

A New Way to Select the Best Control Valve, 16 pp. This three-article reprint takes a fresh look at the problem of specifying process flow control valves. The author gives rules for selecting the right valve characteristics based on static and dynamic considerations, takes into account the influence of piping on valve performance, and tackles the problem of sizing valves for maximum flow and for control rangeability. 50 cents.

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Fundamentals of Tie-Motor Control, 12 pp. Although high-powered synchro-tie systems have been around for a long time, only recently has enough experience been logged to put their design on a scientific, rather than cut-and-try, basis. This reprint examines the types of motors that can be used in the light of the application characteristics, and considers the special circuit designs that are required. 30 cents.

Applying Phase-Plane Techniques to Nonlinear System Design, 16 pp. This

Continued on page 218

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Economics in Control, December 1958, 24 pp. A special report covering the economic aspects of modernizing with control systems. It starts off with a guide to the financial factors of modernization, then tells the control engineer how to spot opportunities where the addition of instrumentation and control equipment will earn money, and concludes with nine case histories showing specific benefits of modernizing with control systems. 50 cents.

First-Hand Report on Control Inside Russia, November 1958, 16 pp. A team of 14 U. S. control engineers representing the American Automatic Control Council reports on the status of automatic control in Russia. Each expert gives impressions of progress in his field of interest based on visits to Russian user plants and research facilities. 40 cents.

How to Calculate a Control Earning Index, 12 pp. Shows a four-step method for predicting the increment of improved plant economy resulting from the addition of instruments and controls, and reports on experience in applying this method to three typical industrial processes. 30 cents.

Servo Design Techniques, 32 pp. A reprint of six related articles describing various electromechanical servo design techniques. Items include tachometer limiting, force-reflecting servos, calculating performance of drag-cup tachs, dual-mode servo compensation, applying packaged servo actuators, and cascading resolvers without amplifiers. 65 cents.

What's Available in Flowmeters, 24 pp. A comprehensive coverage of positive displacement, velocity, and mass flowmeters, including characteristics, applications, and typical manufacturers; plus details of a special drag disc meter. 50 cents.

Selecting and Applying Control Timers, 24 pp. A compilation of four articles including a tabular description of timer functional parts, criteria for selecting and applying control timers, a tabular listing of available timer types and their characteristics, and techniques for custom-designing controls for time-based routines. 50 cents.

What the Control Engineer Should Know About Reliability, April 1958, 8 pp. Not intended as a comprehensive treatise, but rather as a guide to aim the control engineer in the right direction, this staff-written article discusses the new concept of systems effectiveness, and briefly covers techniques for measuring reliability, predicting reliability, improving reliability, and costing reliability. Up to date reference sources increase the value. 20 cents.

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Continued on page 220

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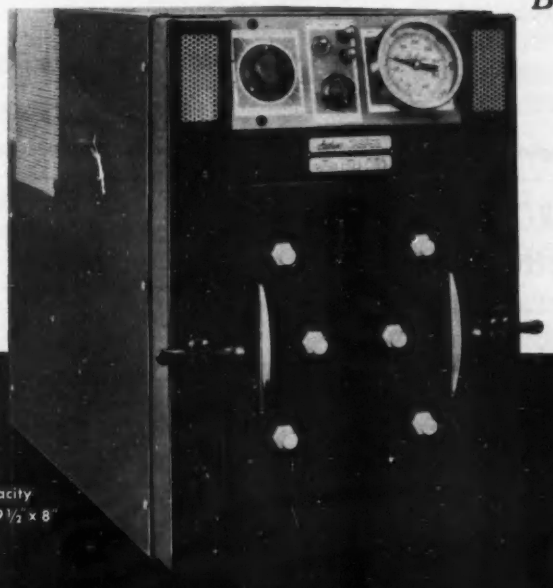

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REPRINTS cont'd

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Basic Data on Process Control, 24 pp. A grouping of five articles on flow-process control, including Basic Concepts of Feedback Control, Selecting Loops for Critical Control, Direct or Reverse Controller Actions, Modifying Valve Characteristics to Fit the Process, and Using Capacitance for Accurate Level Measurement. 50 cents.

How to Simulate Dead Time, 6 pp. Three tricky techniques for simulating dead time or transport lag. One's electronic, another is pneumatic mechanical, and the third uses magnetic tape. A useful reference for control engineers concerned with process simulation. 15 cents.

Transistor and Thyratron Power Amplifiers, 28 pp. These three articles—one on transistors and two on thyratrons—were prompted by the increasing control application of transistors at low-power amplifiers and thyratrons as high-power amplifiers. In each case the emphasis is on practical application, circuit design, system stabilization, etc. 50 cents.

Static Switching Devices—New Tools for Industrial Control, May 1957, 28 pp. An independent consultant analyzes the complete field of industrial static-switching systems. Starting off with a review of basic switching logic, he covers circuit characteristics of the fundamental devices, commercially-available systems, actual applications, etc. 50 cents.

The Use of Digital Computers in Science in Business, and in Control, 112 pp. A collection of 14 articles published over a period of two years as the Digital Application Series. Prominent authorities cover the application, programming, overall system design, and commercial availability of digital computers in all phases of business, industry, and the military. $3.

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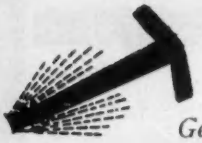

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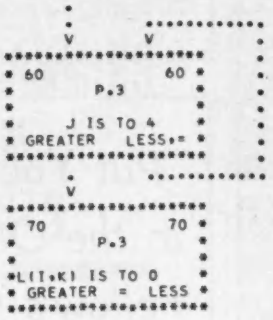

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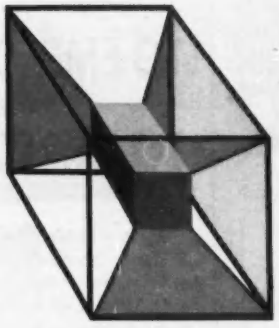

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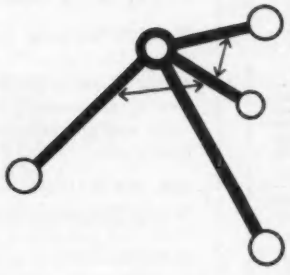

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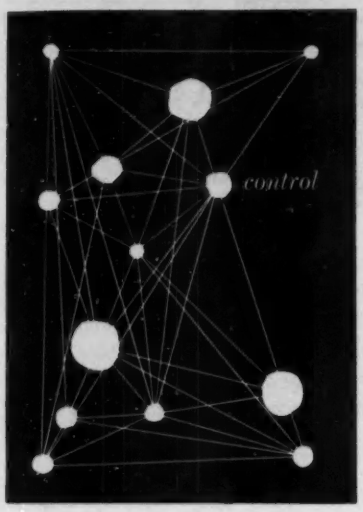

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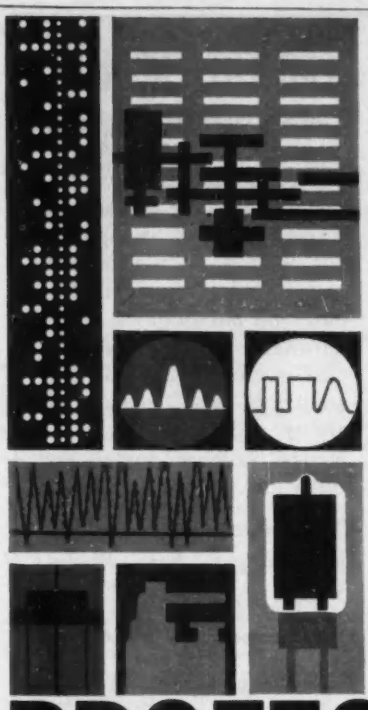

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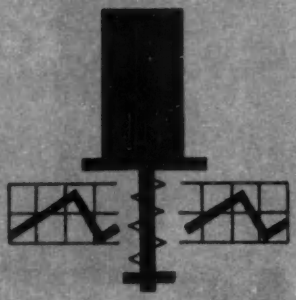

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ADVERTISING IN THIS ISSUE

AGA Div. Elastic Stop Nut Corp. of America 215
AMP Incorporated 154
Abrams Instrument Corp..... 208
Advanced Technology Laboratories.. 218
Allen Bradley Co..... 156
Allis-Chalmers Hydraulic Division.. 207
American Bosch Arma Corporation.. 118
American Engineering Company.... 62
American Meter Co..... 217
Ampex Instrumentation 31
Ampex Magnetic Tape..... 10
Applied Science Corporation of Princeton 86
Arnoux Corporation 48, 49
Assembly Products, Inc..... 198
Audio Devices, Inc..... 178
Automatic Electric 88
Autonetics, a Division of North American Aviation, Inc..... 85

Bailey Meter Company..... 60
Baldwin Lima Hamilton..... 213
Beaver Precision Products, Inc..... 206
Beckman Scientific & Process Instruments Div. 173
Bell Telephone Laboratories..... 41
Bendix Aviation Corporation
Pacific Division 81
Red Bank Division..... 90
Research Laboratories Division.... 212
Scintilla Division 65
Black, Sivalls & Bryson, Inc..... 47
Borg Equipment Divison, Amphenol-Borg Electronic Corporation..... 203
Bourns, Inc. 52, 53
Bowmar Instrument Corporation... 160
Brooks Rotameter Company..... 36
Brush Instruments 33, 34
Bulova Industrial & Defense Sales... 66

Chester Cable Corp..... 39
Clare & Co., C. P..... 63
Clary Electronics Division..... 199
Clevite Transistor Products..... 77
Clifton Precision Products Co., Inc. 91
Comar Electric Company..... 172
Computer-Measurements Company.. 5
Conoflow Corporation 180
Consolidated Electrodynamics 25
Control Division, Magnetics, Inc.... 82
Convair Instruments 29
Cope, T. J., Division of Rome Cable Corporation 162
Cubic Corporation 93

Dahl Company, Inc., George W.... 211
Daystrom Pacific Div., Daystrom, Inc. 37
Daystrom Transicoil Div., Daystrom, Inc. 72
Denison Engineering Division, American Brake Shoe Co..... 218
Donner Scientific Company..... 7

Eagle Signal Company..... 168
Eastern Air Devices, Inc..... 57
Eastman Kodak Company..... 217
Edison Industries, Thomas A..... 89
Electro-Measurements, Inc. 202
Electro Products Laboratories..... 207
Electronic Associates, Inc..... 94
Electronic Products Div., Post Machinery Co. 215
Essex Wire Corp., RBM Controls Div. 15

Fairchild Controls Corporation..... 182
Fenwal Incorporated 74
Fischer & Porter Co.....Fourth Cover
Fisher Governor Company.....8, 9
Foxboro Company, The.....69, 70
Friden, Inc. 201

G-M Laboratories, Inc..... 196
GPE Controls, Inc..... 151
GPS Instrument Co., Inc..... 204
The Garrett Corporation, AiResearch Manufacturing Div. 46
General Electric Co., Semiconductor Products Dept. 71, 152, 153
General Instrument Corporation.54, 55
General Mills, Mechanical Div..... 226
General Radio Company..... 27
Genesys Corporation 179
Gulton Industries, Inc..... 205
Gurley, W. & L. E..... 123

Haydon Division of General Time Corporation 67
Hays Corporation, The..... 185
Heath Company, Division Daystrom, Inc. 197
Heinemann Electric Company..... 186
Hewlett-Packard Company 102
Hoffman Electronics Corporation... 45
Holtzer-Cabot Motor Division, National Pneumatic Co., Inc..... 188

Industrial Timer Corporation..... 148

Kearfott Company, Inc..... 58
Kensico Tube Co., Inc..... 61
Kepco, Inc. 20
Kintel, Div. Cohu Electronics, Inc. 16, 73
Kintronic Div. Chicago Aerial Industries, Inc. 213
Kollmorgan Optical Corporation.... 181

Lambda Electronics Corp..... 195
Leeds & Northrup Co..... 1
Librascope, Inc. .....Second Cover
Litton Industries 219
Lockheed Electronics & Avionics Division 187

Markite Products Corporation..... 56
Marotta Valve Corporation..... 190

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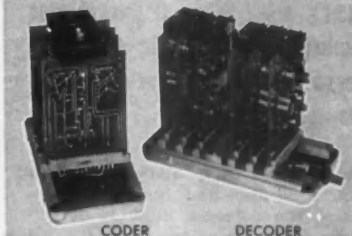

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General Mills

Martin Activation 177
McGraw-Hill Book Co., Inc..... 209
Metals & Controls Division of Texas Instruments Incorporated 209
Metron Instrument Company..... 210
Micro Switch Div., Minneapolis-Honeywell 183, 184
Midwestern Instruments 174
Minneapolis-Honeywell 142, 143
Boston Division 84, 176
Minnesota Mining & Mfg. Co..... 169
Monitor Systems Incorporated, a Subsid. of Epsco Incorporated.... 2
Moog Servocontrols, Inc..... 13
Moore Associates, Inc..... 225
Moseley Co., F. L..... 158
Muirhead & Company, Lt'd..... 24
Mycalex Electronics Corporation... 92

National Acme Co., The.....51, 167
New Departure Division, General Motors Corp. 96
Norwood Controls 214

Philco Corp., Lansdale Tube Co. Div. 100
Precision Instrument Company..... 211

RBM Controls Div., Essex Wire Corp. 15
Radio Corporation of America...75, 175
Reflectone Electronics, Inc..... 200
Republic Flow Meters Co..... 189
Richardson Scale Company..... 210
Rome Cable Corporation.....42, 43

Sanborn Company 64
Servonic Instruments, Inc..... 215
Sigma Instruments, Inc..... 28
Sorenson & Company, Inc..... 192
Sperry Semiconductor Division, Sperry Rand Corp..... 79
Spiroid Division of Illinois Tool Works 32
Sprague Electric Company..... 6
Statham Development Corp..... 219
Statham Instruments, Inc..... 14
Stepper Motors Corporation..... 164
Stevens Arnold, Inc..... 166
Superior Tube Company..... 78

Tally Register Corporation..... 205
Taylor Instrument Companies...98, 99
Technology Instrument Corp. Third Cover
Telechrome Mfg. Corp..... 171
Teletype Corporation 76
Texas Instruments Incorporated.... 18, 19, 165, 191
Thermo Electric Co., Inc.....50, 208
Tinsley Laboratories, Inc..... 216
Tomkins-Johnson Co., The..... 44
Transitron Electronic Corporation... 59
Tung-Sol Electric Inc..... 83

Union Switch & Signal Div., Westinghouse Air Brake Co..... 12
Unistrut Products Company..... 35

Varian Associates 134
Veeder-Root, Inc. 80
Vernistat Division, Perkin-Elmer Corporation 38
Vickers Incorporated, Electric Products Div. 87
Aero Hydraulics Division..... 11

Wallace & Tiernan, Incorporated... 26
Wang Laboratories, Inc..... 219
Westinghouse Air Brake Company.. 40
Wiancko Engineering Company.... 170

CLASSIFIED ADVERTISING
F. J. Eberle, Bus. Mgr.

EMPLOYMENT OPPORTUNITIES 220-224

ADVERTISERS INDEX

Bell Aircraft Corp..... 224
Control Data Corporation..... 220
Esquire Personnel 224
General Electric Company.....220-223-224
Honeywell, Aeronautical Div..... 222
International Business Machines Corp.... 221
Koppers Company (Metal Products Div.) 224
Monarch Personnel 220
Panellit, Inc. 222
Perkin-Elmer Corp. 222
Square D. Company..... 220
Union Carbide Nuclear Company, Div. of Union Carbide Corp..... 222

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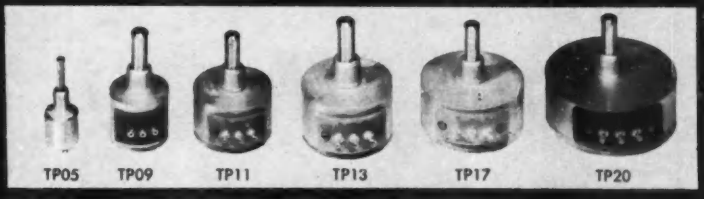

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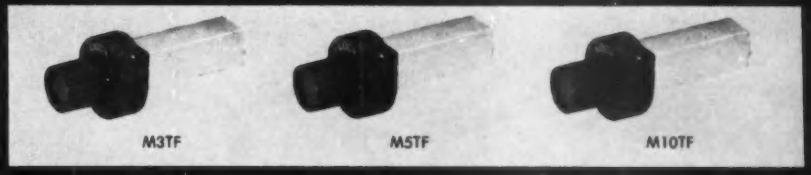

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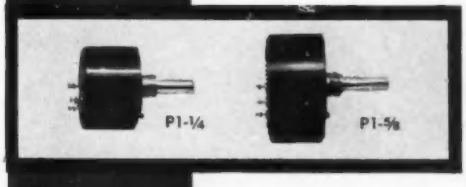

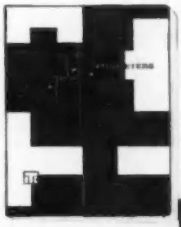

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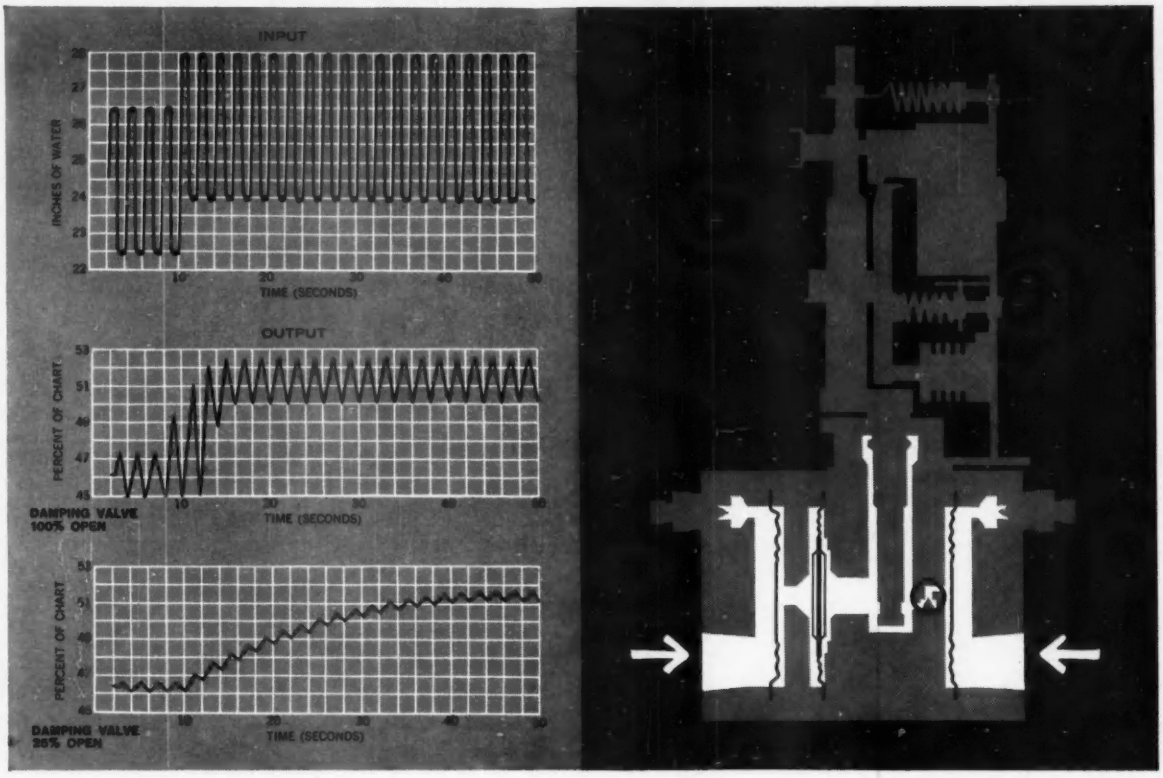

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* * *

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